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CHANNEL CHANGE OF UNREGULATED AND REGULATED STREAMS NEAR THREE U. S. GEOLOGICAL SURVEY GAGING STATIONS, UINTA MOUNTAINS, UTAH

FINAL REPORT

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SUMMARY

The purpose of this report is to summarize channel change of three streams that drain the western and southern parts of the Uinta Mountains. In so doing, we illustrate the use of several monitoring techniques and strategies to detect channel change of coarse bedded mountain streams. Measurements at these streams were originally made in the late 1990s by Smelser (1997) and Stamp (2000); repeat measurements were conducted in 2003. The gaps between these repeated measurements span from six to seven years. Channel change during this period demonstrates that channels naturally adjust to watershed-scale variation in runoff, and also adjust to site-scale factors such as tree throw and large woody debris accumulation. In some cases, the trajectory of channel changes has likely been influenced by dams and trans-basin diversions of stream flow.

We combined precise measurements of monumented cross-sections and longitudinal profiles with pebble counts and detailed geomorphic mapping based on planform surveys. Each of these methods has inherent strengths and weaknesses. Monumented cross-section surveys yield precise data that are easily replicated, but cover a limited portion of the study reach, and do not identify any changes that take place between them. Longitudinal profiles yield precise data that covers an entire study reach, but are harder to replicate because each profile survey follows the thalweg of that particular year. Furthermore, a longitudinal profile survey, which focuses solely on the bed and water surface elevations at the thalweg, will miss planform changes taking place along banks, in side channels, and across bar and floodplain surfaces. The cross-section and longitudinal profile survey data were supplemented by mapping the valley flat and channel landforms, and by replicating past photographs. These maps helped us to determine the lateral extent of the vertical channel changes measured at the cross-sections and longitudinal profiles, as well as characterize the types of features that changed. The replication of photos helped to characterize the types of change taking place, but also captured changes that the quantitative methods failed to identify.

Thus, the changes documented by the longitudinal profile surveys help to identify the upstream and downstream extent of changes captured with monumented cross-sections, and are better understood when used in conjunction with planform maps. However, the natural variation of channel change types and magnitudes is large, and has the potential to mask human induced changes.

INTRODUCTION

Adjustments in the form of unregulated mountain channels are driven by change in stream flow, sediment supply, and by local factors that restructure the channel, such as log jams and tree throw. The inherent natural variation of channel form through time must be characterized if one is to distinguish human-caused channel change from natural variability.

A monitoring program was initiated in the mid-1990s for selected streams of the Uinta Mountains in north-eastern Utah (Smelser, 1997; Stamp, 2000). Here, we summarize measurements made in 2003 of North Fork Provo River, Lake Fork River, and Rock Creek in an effort to provide insight about natural and human-caused variation of channel form.

STUDY AREA AND HYDROLOGY

The Uinta Mountains are Utah's highest, and run from the east to west for 260 km between Kamas, Utah, and Maybell, CO. The western part of the range drains to the Great Salt Lake and the eastern two-thirds of the range drain to the Green River (Fig. 1). The high-elevation parts of the range are administered by the Ashley, Uinta, and Wasatch-Cache National Forests, while an eastern section of the range is within Dinosaur National Monument. The bedrock and glacial geology of the range are described by Dehler et al. (2005).

The channels that are the subject of this monitoring report are cobble-bedded and occur in relatively narrow valleys. The valleys transported glacial outwash from upstream glaciers during the Pleistocene (Fig. 2). In some cases, the upstream watersheds are within the High Uintas Wilderness and have no roads or logging. Monitoring of the channels downstream from these wilderness areas provides a chance to evaluate natural variability of relatively pristine channels.

The three study reaches in this monitoring report contain stream flow gaging stations that are either active or discontinued. The Lake Fork gage (USGS #09289500) remains active, while the North Fork Provo River gage (USGS #10153800) was discontinued following the 1996 water year, and the Rock Creek gage (USGS #09278500) was discontinued following the 1988 water year. These gaging stations were established by the U. S. Geological Survey near where the streams leave the mountain front and are diverted. Thus, the gaging stations are often located upstream from any significant flow diversions or human alteration of their watersheds. The Rock Creek study reach is an exception to this rule, as the reach lies approximately 4 km downstream from Upper Stillwater Dam that was completed in 1987. This dam reduced the mean annual flood magnitude by approximately 70% of its pre-dam value, and supplies water to the Stillwater Tunnel which functions as a trans-basin diversion for the Central Utah Project.

Peak stream flows between 1996 and 2003 ranged from low to moderate (Fig. 3). The largest estimated mean daily flow at the North Fork Provo River during this period was 13.4 m^3/s and took place in the 1997 water year. This flood magnitude corresponded with approximately a 7 year recurrence interval. In the Lake Fork River monitoring reach the maximum mean daily flows during this period were approximately 41.9 m^3/s, took place in 1997 and 1999, and corresponded with a 7 year recurrence interval. At Rock Creek the largest mean daily flow was approximately 37.4 m^3/s, took place in 1998, and corresponded with a 2 year recurrence interval based on analysis of the pre-dam flow record.

Flow data were estimated for the North Fork River based on correlations with flows on a downstream gaging station on the Provo River (USGS #10154200). The North Fork Provo River watershed at the study reach is approximately 15% of the size of the Provo River watershed at the downstream gaging station. A regression equation was developed that predicted North Fork River flows based on twenty years of coincident data for the two gages. This equation predicted the annual maximum mean daily flow for the North Fork Provo River with an average error of approximately 1.4 m^3/s, or within about 15% of the mean annual peak flow for the North Fork Provo River. Upper Stillwater Reservoir release data provided by the Central Utah Water Conservancy District was used as a surrogate for Rock Creek flows.

METHODS

Our effort was to comprehensively and precisely describe channel change. Thus, we combined precise measurements of monumented cross-sections and longitudinal profiles with detailed geomorphic mapping based on planform surveys of the study reaches. Pebble counts served to track changes in the grain size distribution of the bed surface.

Different strengths and weaknesses are inherent to the various methods employed to detect channel change. Monumented cross-section surveys yield precise data that are easily replicated in space, but cover a limited portion of the study reach, and do not identify any changes that take place between them. Longitudinal profiles yield precise data that cover an entire study reach, but are harder to replicate because each profile survey follows the thalweg of that particular year. Furthermore, a longitudinal profile survey, which focuses solely on the bed and water surface elevations at the thalweg, will miss planform changes taking place along banks, in side channels, and across bar and floodplain surfaces. The cross-section and longitudinal profile survey data were supplemented by mapping the valley flat and channel landforms, and replicating past photography. These maps helped us to determine the lateral extent of the vertical channel changes measured at the cross-sections and longitudinal profiles, as well as to characterize the types of features that changed. The replication of photography helped to characterize the types of change taking place, but also occasionally captured changes that the quantitative methods failed to identify.

Monitoring sites were approximately 20 channel widths in length, and previously created maps and surveys describe the channel and associated valley flat (Smelser, 1997; Stamp, 2000). Channel cross-sections are monumented and were originally surveyed with an engineer's level and were resurveyed with total station. Longitudinal profiles were also surveyed with a total station. Planform mapping was updated in the summer of 2004 based on 2003 survey data. The 2003 survey points were overlain on the maps produced in the late 1990s, and the maps were updated. The peak flows that occurred in spring 2004 were relatively low in magnitude, so it was assumed that only minor channel changes had taken place between the survey and mapping years. The precise location of past pebble counts were known for the North Fork Provo River and Rock Creek, while a reach-averaged median grain size was available for Lake Fork.

RESULTS

North Fork Provo River near Kamas (U. S. Geological Survey gaging station 10153800)

Monitoring at North Fork Provo River demonstrates the crucial role of local site factors in controlling channel change. Some parts of the channel changed little whereas adjacent parts of the channel changed significantly.

The monitoring reach is approximately 100 m upstream from the confluence of the North Fork with the main stem Provo River (Fig. 4). The watershed area upstream from the gage is 63.2 km^2, and the watershed is relatively pristine with few roads and little logging. The monitoring reach is steep, 0.0217 m/m, and the bed is coarse (D_{50} = 125 mm; D_{84} = 265 mm) (Smelser, 1997). The valley flat is approximately 4 times wider than the average bankfull channel width, and the stream occasionally is at the margin of the valley flat, where hill slope material directly enters the channel. The active floodplain fills only a small (< 4%) part of valley flat, and most of the valley flat is higher than the stage of the largest historic flood.

Bankfull discharge is approximately 10.5 times greater than the mean annual discharge. Smelser (1997) estimated bankfull discharge to be 11.7 m^3/s, and mean annual discharge between 1963 and 1996 was 1.11 m^3/s. Tracer studies demonstrated that partial bed mobilization occurred in 1996 when the annual peak flow was 1.4 times (16.1 m^3/s) the bankfull discharge, and full bed mobilization occurred during a 10-yr recurrence flood that occurred in 1995 (18.6 m^3/s).

Analysis of USGS discharge measurements demonstrates that cyclic fill and scour of between 0.1 and 0.3 m typically occurs during rise and fall of the annual spring snowmelt flood (Fig. 5). The bed typically fills during rise of the flood, and scours during flood recession at the measurement cross-section. There was no significant long-term change in bed elevation at the measurement cross-section between 1963 and 1996 (Fig. 6); mean summer/fall bed elevation at the measurement cross-section varied through a 0.20 m range: between 2291.87 and 2292.07 m during this period.

Although the other channel characteristics at the USGS measurement cross-section have changed little, significant change of parts of the monitoring reach occurred. The magnitude of these changes illustrates that local channel change can greatly exceed average reach-wide channel change. The major mechanisms of local channel change are log jams and tree throw.

A bank-to-bank log jam formed in the monitoring reach during the 1995 flood. Two large trees had spanned the channel when first surveyed in 1994, and the log jam formed because wood transported from upstream was blocked by these trees. Smelser (1997) observed ponded water to the elevation of the valley flat later in 1995, after the jam had formed. Because stage-discharge analyses indicate that the valley flat surface is not inundated by floods, log jams are the only mechanism by which stage is elevated, and reaches the valley flat.

Following the jam, more than 0.7 m of sediment buried a series of boulder steps upstream (Fig. 7). In 1996, the dam was breached and some of the previously aggraded sediment was scoured (Fig. 8; Fig. 9). Figures 7.B. and 8.B. show that cross-section 10 continued to aggrade overall between the 1995 and 1996 surveys, but that portions of the cross-section were eroding. Figure 9.C. shows the longitudinal extents of changes that took place due to the dam as well as depicts the chronological sequence of bed adjustments. Bed scour and remobilization continued between 1996 and 2003, and a plunge pool developed immediately downstream from the jam (Fig. 10). Remapping of channel elements shows that there was scour of some of the sediment upstream from the log jam and a new pool has been created.

The complexity of local channel change near the log jam is depicted in Fig. 11. Between 1994 and 1995, 603 m^2 of fill, and 147 m^2 of scour occurred in nearly 30 m of channel near the jam. Between 1995 and 2004, 66 m^2 of fill, and 183 m^2 of scour occurred in this area. Accumulated sediment behind the log jam was finer than the bed elsewhere, and probably more closely reflects the transported load delivered from the watershed. The D_{50} of a gravel island near cross-section 12 decreased from 115 to 70 mm between 1994 and 2003 (Fig. 12).

Another mechanism of local scale channel change is tree throw. Bed scour and fill has occurred near cross-sections 2 and 3, where an overhanging tree fell into the channel (Fig. 13). The fill material was finer than the original substrate; D_{50} decreased from 125 to 98 mm between 1994 and 2003. Remapping of the channel and floodplain, identify other cases where large woody debris was contributed to the channel, such as near cross-section 3 and cross-section 7 (Fig. 14). However, these trees were swept away by 2005, and log jams did not develop.

Lake Fork River above Moon Lake, near Mountain Home (U. S. Geological Survey gaging station 09289500)

Monitoring of Lake Fork River demonstrates that channel change can be comprehensively measured, if precise measurements of some places are combined with

less precise maps and photographs of the entire channel. The Lake Fork River stream gage and monitoring reach, is located approximately 500 m upstream from Moon Lake. The upstream watershed of 202 km^2 is mostly within the High Uintas Wilderness area, and there are no diversions or alterations of the natural runoff regime. The annual flow regime is dominated by the spring snowmelt flood, and the 2-yr recurrence flood (28.6 m^3/s) is approximately 9 times greater than the mean annual discharge (3.24 m^3/s) (Stamp, 2000). The stream has a coarse bed and is steep. The D_{50} of the bed is 154 mm and that of the bars exposed at base flow is 77 mm; slope of the monitoring reach is 0.023 m/m. The valley flat is about 13 times wider than the bankfull channel, and is thus proportionally wider than the North Fork Provo River.

There are five monumented cross-sections in the monitoring reach (Fig. 15). Channel change took place by way of lateral channel migration as well as bed scour and fill. Furthest upstream, cross-section one was dominated by lateral scour on river left, while cross-section two showed bed degradation across most of the main active channel and about 1.4 m of lateral scour at the right bank. Cross-section three was more stable, showing about 1 m of lateral erosion on the left bank; the rest of the channel bed showed minor adjustments that may reflect either individual cobbles or different placement of survey points. Cross-section four showed minor mid-channel aggradation and bank erosion at river right, while cross-section five showed significant degradation of the main channel near a mid-channel bar and lateral erosion at the right bank.

Longitudinal profile surveys demonstrate the extent of bed changes measured at the cross-section resurveys (Figs. 16 and 17). The erosion measured at cross-section two extends almost 20 meters upstream and downstream from the cross-section (Fig. 18). Another case of significant thalweg erosion took place near the downstream reach boundary. In this case, the main channel moved significantly to river right, and in so doing accomplished a change in thalweg elevation (Fig. 19). Thus, the changes documented by the longitudinal profile surveys help to identify the upstream and downstream extent of changes captured with monumented cross-sections, and are better understood when used in conjunction with planform maps.

Repeated planform mapping further illustrates the nature of channel adjustments. Channel adjustments identified by repeated mapping include the expansion of the furthest downstream mid-channel gravel bar in the reach, and lateral scour of the right bank that also occurred at the downstream end of the study reach (see figure 19). Mapping efforts documented a total of 755 m^2 of deposition, and 2,549 m^2 of erosion (Fig. 20).

Bed surface substrate measurements were conducted in the form of pebble counts. Specific locations and original measurement data from 1997 were unavailable; a reach-average D_{50} of 154 mm was produced from pebble counts conducted on the bed surface in the channel and on cobble bar surfaces. 2005 pebble counts were conducted on a number of active depositional surfaces. These samples yielded an area-weighted average D_{50} of 141 mm (Fig. 21).

Some significant changes took place in Lake Fork River's active channel that eluded detection by cross-section and longitudinal profile surveys, mapping, and pebble counts. Without the benefit of past photographs taken from known locations, these changes would have been missed entirely. Figure 22 shows two examples of change documented solely by photography. The first example shows significant bank erosion including the scour of a mature willow clump, and the movement or removal of a large boulder near the same bank. The second example documents the movement of a large mid-channel boulder. The photographic documentation does not allow the precise quantification of these changes, but it does give an approximation of the magnitudes of changes that the quantitative methods described in this paper failed to capture as applied here.

Rock Creek near Hanna (U. S. Geological Survey gage 09278500)

Measured channel changes at Rock Creek demonstrate that heavily regulated stream flow does not always lead to dramatic channel change. The drainage area upstream from this gage is 316 km^2, larger than the other monitoring sites. In contrast to the other sites, stream flow has been significantly altered by Upper Stillwater Dam completed in 1987, and by a trans-basin diversion from the reservoir. Mean annual discharge prior to dam construction was 4.44 m^3/s. It is difficult to precisely determine changes in stream flow at this site, because gaging was discontinued in 1988. However, mean annual flow between 1989 and 1994 at a gage upstream from the original gage, and whose drainage area is 82% of that at the monitoring site, was 0.8 m^3/s, suggesting that the natural flow regime has been reduced by approximately 80%. The gradient of the reach is 0.0111 m/m, less than the other sites, and the bed is coarse (D_{50} = 165 mm) (Smelser, 1997). Analysis of flow releases from Upper Stillwater Reservoir reveals that the average annual peak discharge through the study reach has been reduced by approximately 70% since dam closure.

Numerous sources of sediment supply, such as channel contacts with unconsolidated hillslopes, and a valley floor composed primarily of glacial till occur between the dam and the study reach (figure 23). Due to this reach's geologic and hydrologic context, a trajectory of change resulting from the upstream change is difficult to predict without comprehensive pre- and post-dam sediment transport measurements in the reach. Smelser (1998) identified a surface typically inundated by pre-dam floods as well as a lower elevation surface inundated by post-dam flows. Subsequent survey and mapping efforts, have identified cases of relatively minor channel changes occurring primarily in the upstream portion of the reach that contains multiple channels and braid-forming islands.

Cross-section surveys from 1995, 1996, and 2003 show minimal channel change (Fig. 24). Even the upstream-most cross-section that crosses multiple active channels showed no significant changes between 1996 and 2003. Scouring of a log jam or beaver dam remnant took place on the main channel's river-right bank between 1995 and 1996, and was further substantiated by mapping exercises.

The longitudinal profile shows several areas of apparent change in thalweg elevation (Fig. 25). When taking into account the placement and density of survey points, it seems that much of the apparent change in the lower reach can be attributed to the 2003 survey capturing the tops and bottoms of individual steps, while the previous surveys identified the general thalweg elevation (Fig. 26). In the upstream portion of the reach the main channel has apparently filled one pool and formed several others in between 1995 and 2003. Longitudinal profile point densities in 1996 were insufficient to indicate the presence or absence of two of the new pool features of this size, while the 1995 points' placement promotes skepticism as to the validity of change observations between 1995 and 2003 (Fig. 27).

The side channels in the upstream half of the study reach exhibited the bulk of planform changes. In one case, a vegetated island that separated the main channel from the side channel at river right eroded laterally to allow flow back to the main channel. A pool near, and upstream from, this erosion in the side channel has filled in. Two pools were scoured, where a run had existed in the river right side channel. Near the upstream extent of the river right side channel, deposition of sand and fine gravel formed a low floodplain surface, where the return flow from a small overflow channel previously entered the dominant side channel at river right. All of these changes took place in the upstream, lower gradient, braided section of the monitoring reach. Throughout the reach, planform mapping exercises documented a total of 977 m^2 of erosion and 609 m^2 of deposition (Fig. 28).

Pebble counts documented a significant shift toward finer bed surface substrates (Fig. 29, see figure 28 for sampling locations). The two upstream pebble counts took place on depositional features partially submerged by low summer flows. The furthest downstream pebble count was conducted on a dry bar on river right with an upper elevation at the post-dam floodplain elevation. Reductions in D_{50} values between 1995 and 2004 ranged from between 60 to 110 mm, while reductions in D_{84} values were between 60 and 175 mm over the same time period.

DISCUSSION AND CONCLUSIONS

Natural variability in channel form over small spatial and short time scales can be sufficiently large to mask changes caused by watershed scale factors. The three study reaches all experienced similar magnitudes of planform channel change between the late 1990s and the 2003/2004 period, regardless of upstream flow manipulation. The two unregulated reaches, North Fork Provo River and Lake Fork River, experienced changes that represent totals of approximately 30 and 19% respectively of their active channel areas either eroding or aggrading between mapping exercises. Rock Creek, a reach with regulated and diverted flows, experienced erosion or deposition over a total of 26% of the post-dam active channel, or 23% of the pre-dam active channel area.

Channel changes detected at these three sites demonstrate that watershed scale changes, such as reduction of flood peaks and of total flow at Rock Creek, as well as local scale changes such as log jams and tree throw, caused several types of channel

change. These changes took place over a time span where annual peak flow magnitudes ranged from low to moderate. Types of change included bed substrate size changes, bank erosion, the deposition of inset alluvial deposits that narrow channels, and bed incision over short reaches.

Several methods were used in monitoring channel change in the study sites to take advantage of their inherent strengths. Precise measurements of monumented cross-sections and longitudinal profiles were supplemented with detailed geomorphic mapping based on planform surveys and by replicating past photographs. Repeated pebble count surveys identified changes in bed and bar surface grain size distribution, as other methods are not capable of capturing these changes. In combination, these methods served to describe channel change not only in the in-channel area, but along the banks and across bar and floodplain surfaces.

In conclusion, the changes documented by the longitudinal profile surveys help to identify the upstream and downstream extent of changes captured with monumented cross-sections, and are better understood when used in conjunction with planform maps. However, the natural variation of channel change types and magnitudes is large, and has the potential to mask human induced changes.

References

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Smelser, M. G. (1997). Geomorphic adjustability of streams draining the Uinta Mountains of Utah. Master of science thesis, Utah State University.

Stamp, M. C. (2000). Hydrologic and geomorphic effects of dams and water diversions on Lake Fork River and Rock Creek, Uinta Mountains, Utah. Master of science thesis, Utah State University.

Figure 1. Location map of the Uinta Mountains in north-eastern Utah. The area includes the North Fork Provo River, the Lake Fork River above Moon Lake, and Rock Creek study sites (From Stamp, 2000).

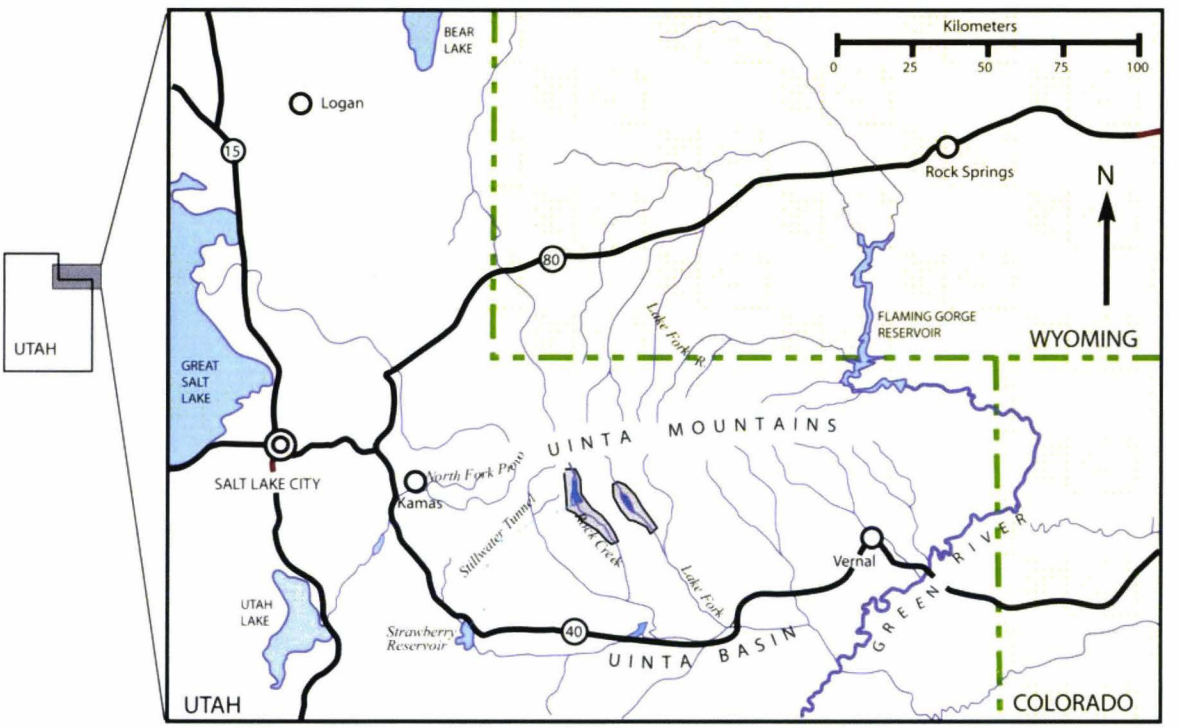


Figure 2. Block diagram of an idealized stream in the Uinta Mountains (From Smelser, 1997)

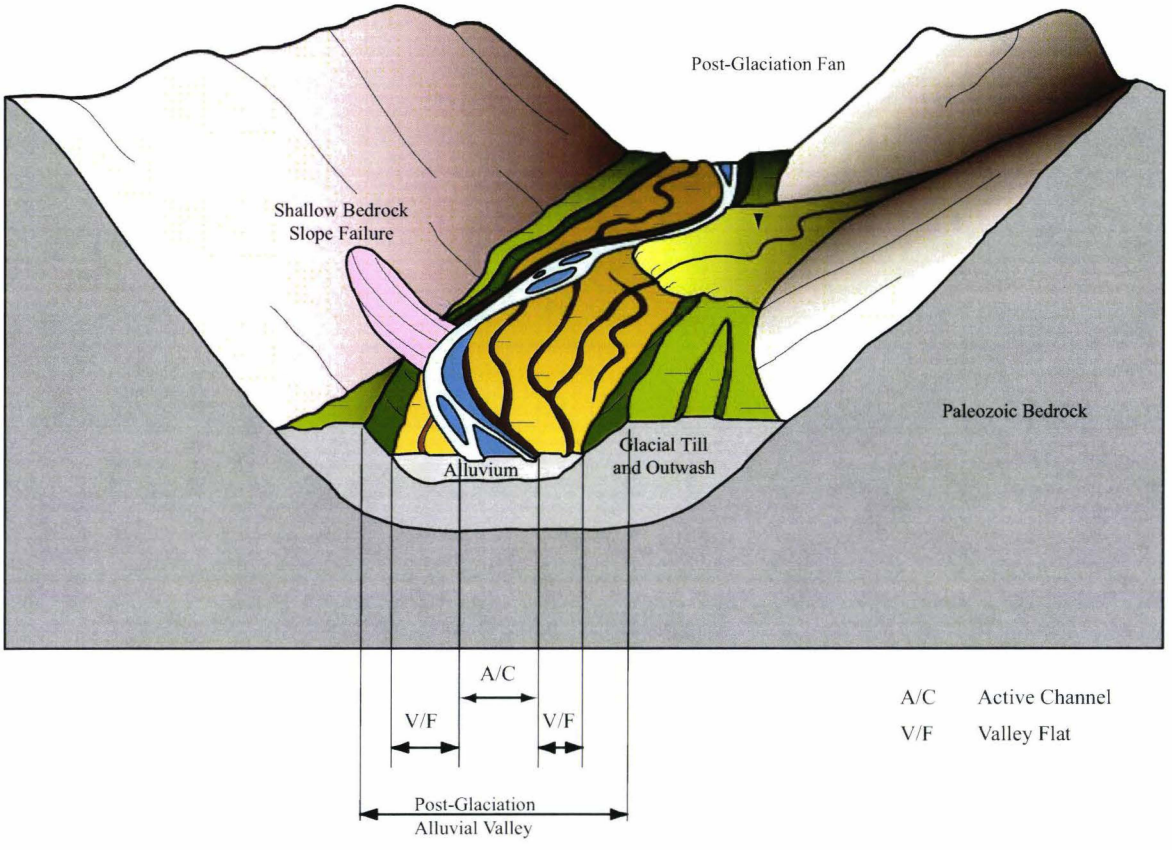
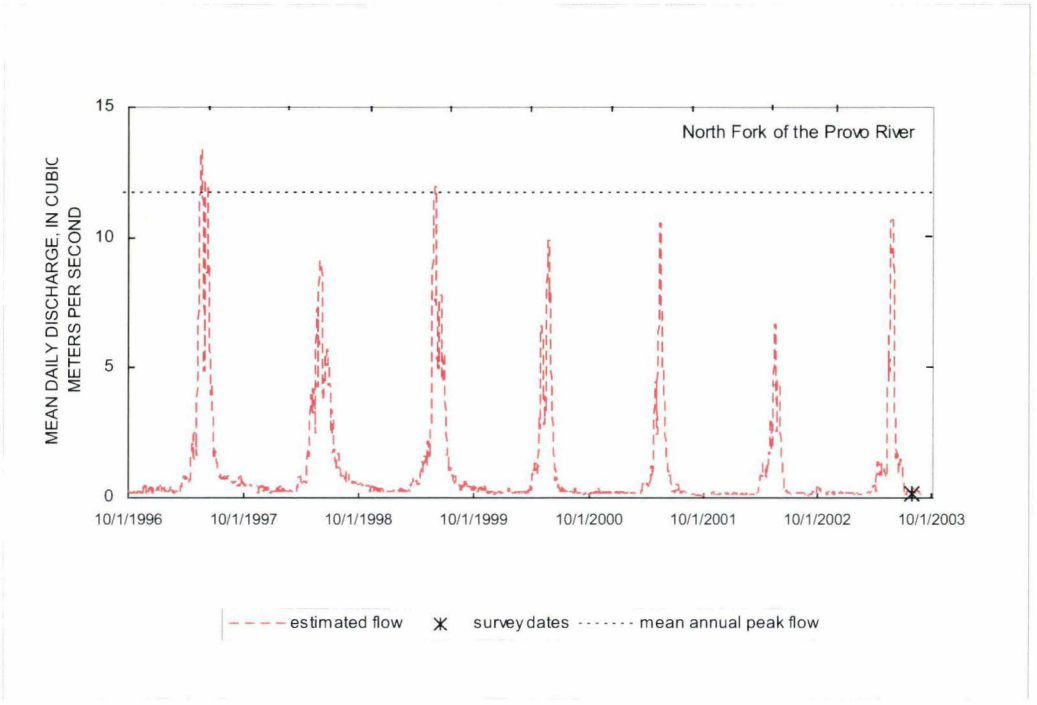
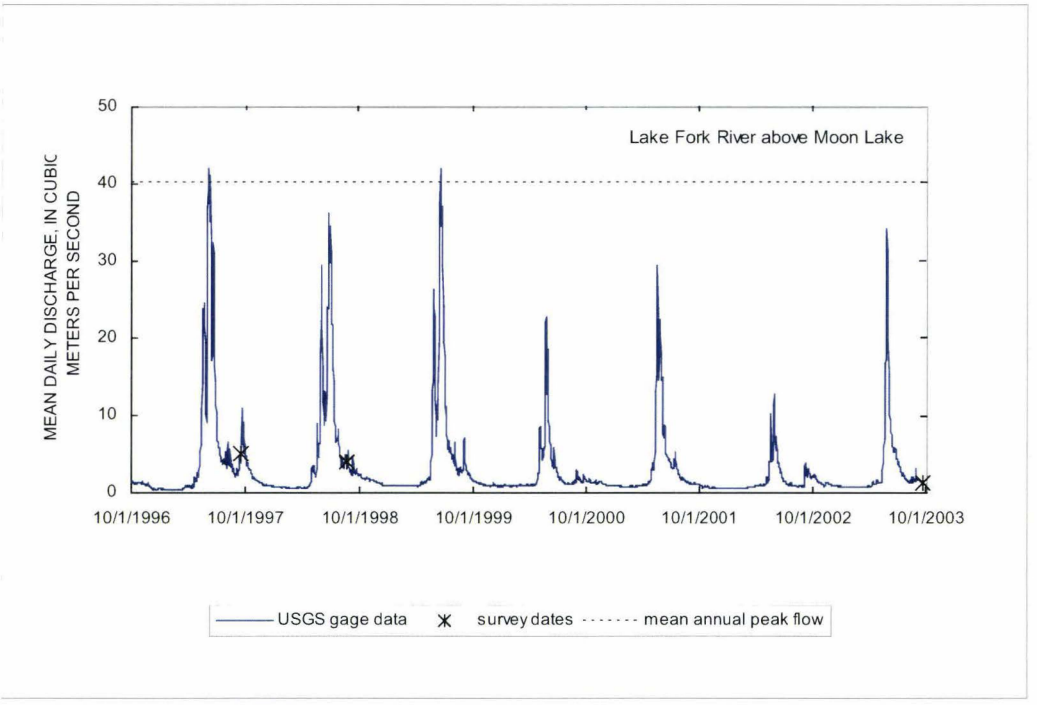


Figure 3. Mean daily discharge at streams on this study between 1996 and 2003. **A.** North Fork of the Provo River. **B.** Lake Fork River above Moon Lake. **C.** Rock Creek.

A.



B.



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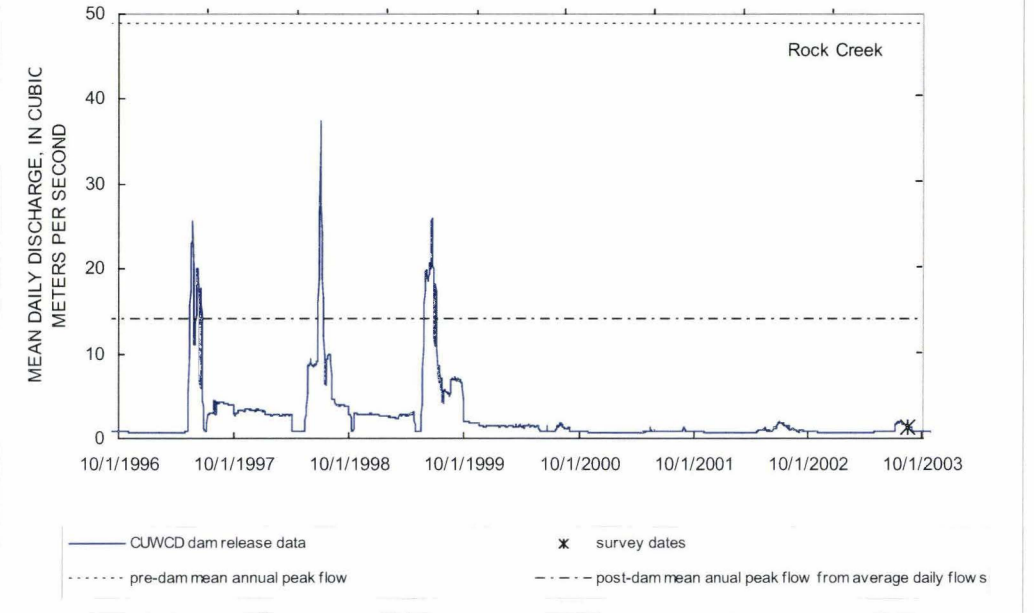

Rock Creek
MEAN DAILY DISCHARGE, IN CUBIC METERS PER SECOND
50
40
30
20
10
0
10/1/1996
10/1/1997
10/1/1998
10/1/1999
10/1/2000
10/1/2001
10/1/2002
10/1/2003
CUWCD dam release data
survey dates
pre-dam mean annual peak flow
post-dam mean anual peak flow from average daily flow s

Figure 4. North Fork River monitoring reach. Simple geomorphic map of the study area that shows the general geologic setting and channel patterns (Smelser 1997).

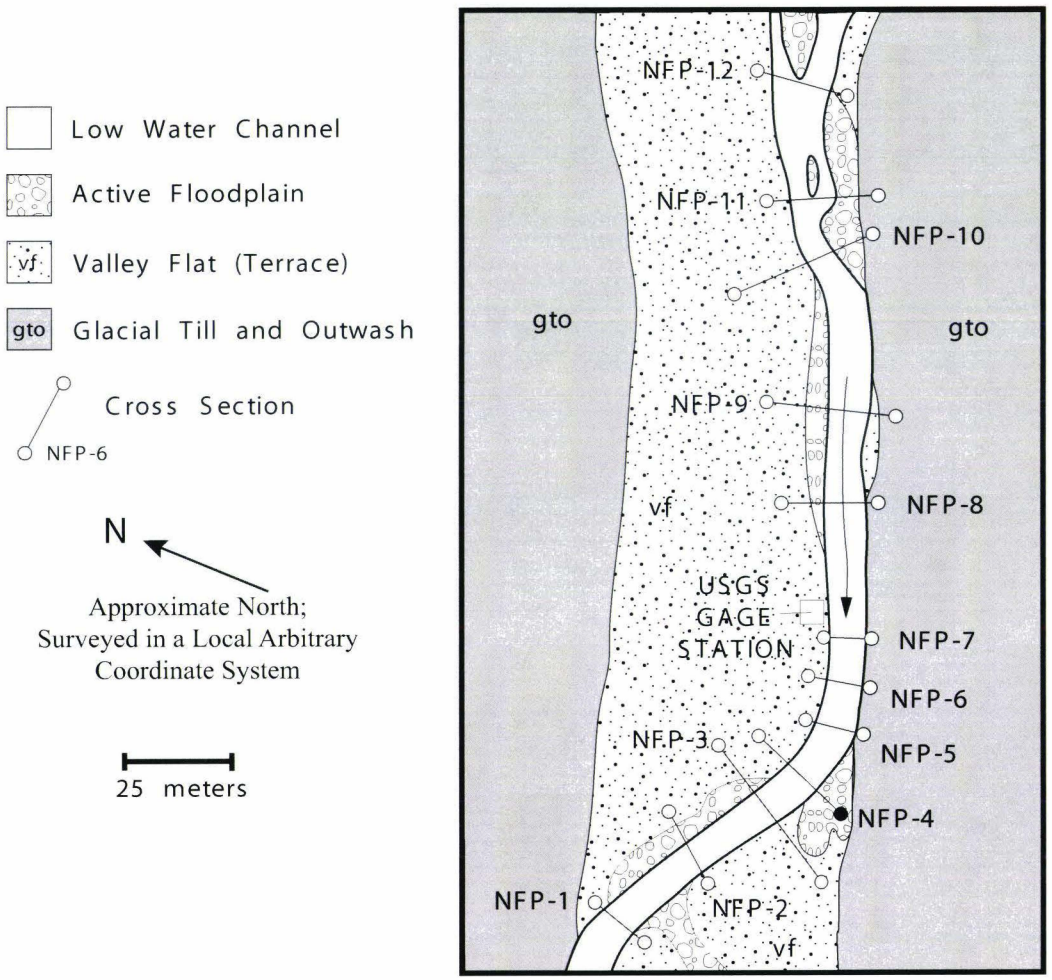


Figure 5. Daily mean discharge measurements and coincident streambed adjustments for two study sites during a decade. Streambed adjustments are shown in the top of each graph, and are quantified along the right ordinate axis as change in bed elevation. The filled circle is a scaled representation of the D_{50} particle size. Annual hydrographs shown along the bottom of each graph are quantified by the left coordinate axis, and the mean annual flood is represented by the horizontal heavy dashed line. The shaded area is for the range of discharges between 0.8 and 1.6 times the bankfull discharge. **A.** North Fork Provo River for the period 1964-1974. Mean annual flood is 11.7 m^3/s. **B.** Rock Creek for the period 1978-1988. Mean annual flood is 48.9 m^3/s (Smelser, 1997).

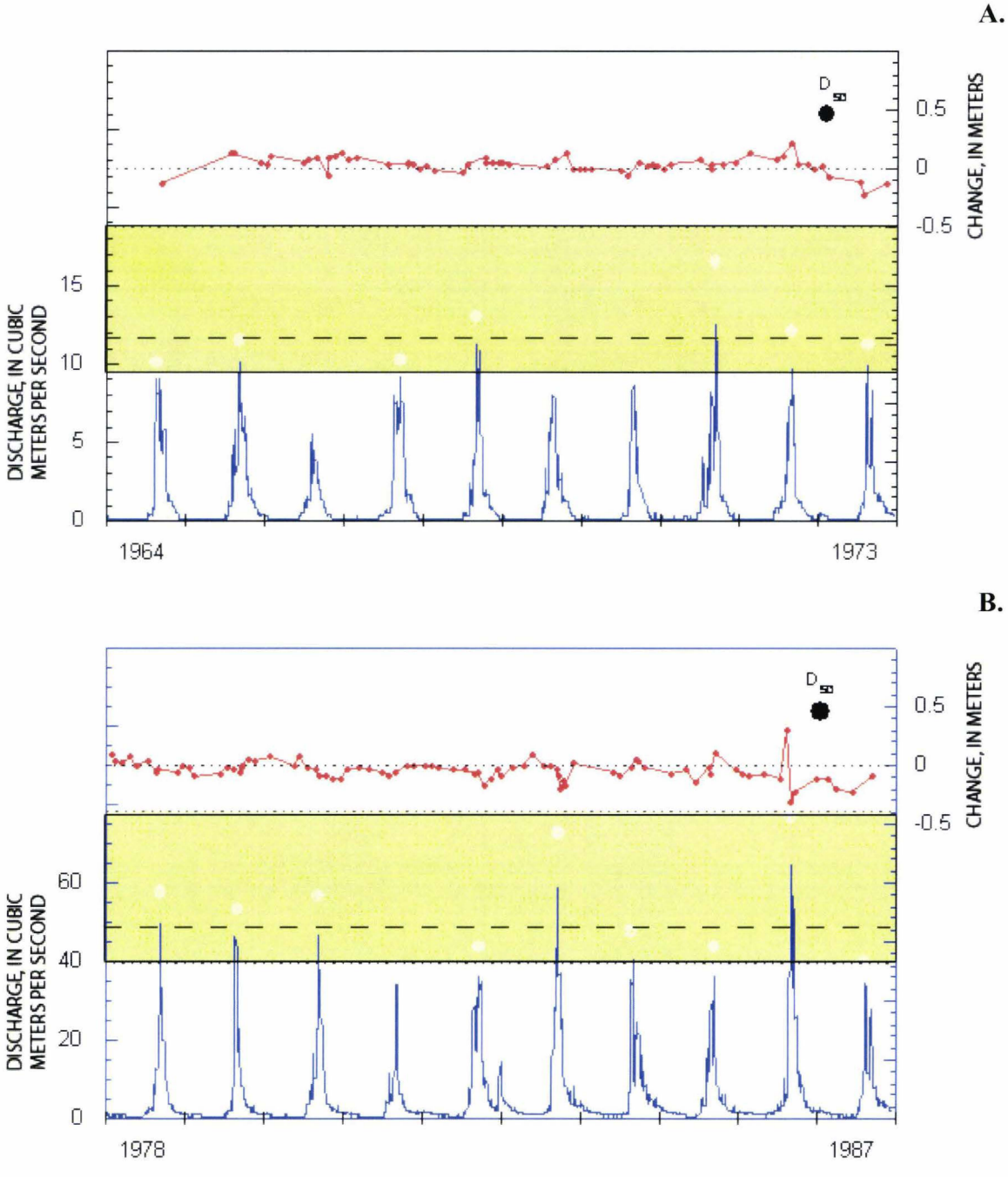
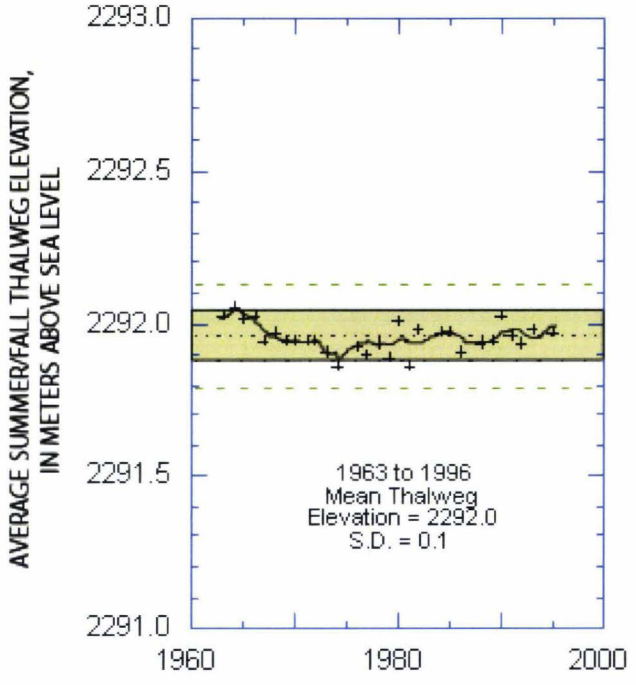


Figure 6. Long term change in bed elevation at the measurement cross-section for two study sites. **A.** North Fork Provo River for 1963-1996. **B.** Rock Creek for 1949-1969, and 1974-1988 (Smelser, 1997)

A.



B.

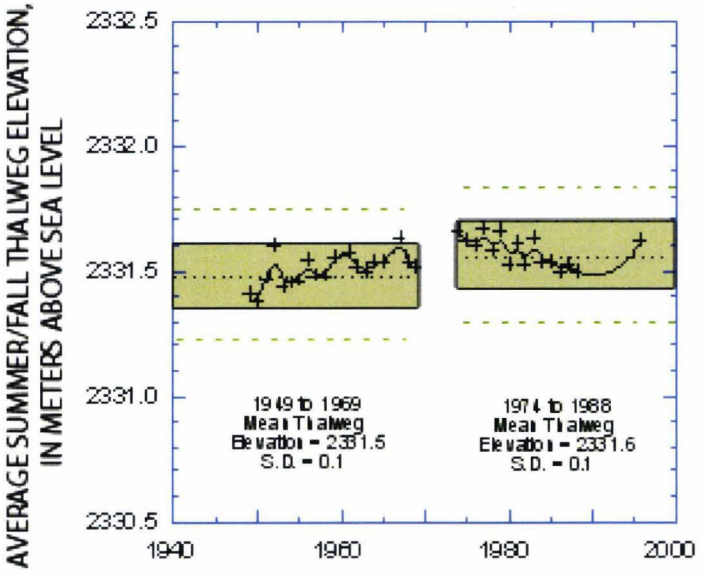
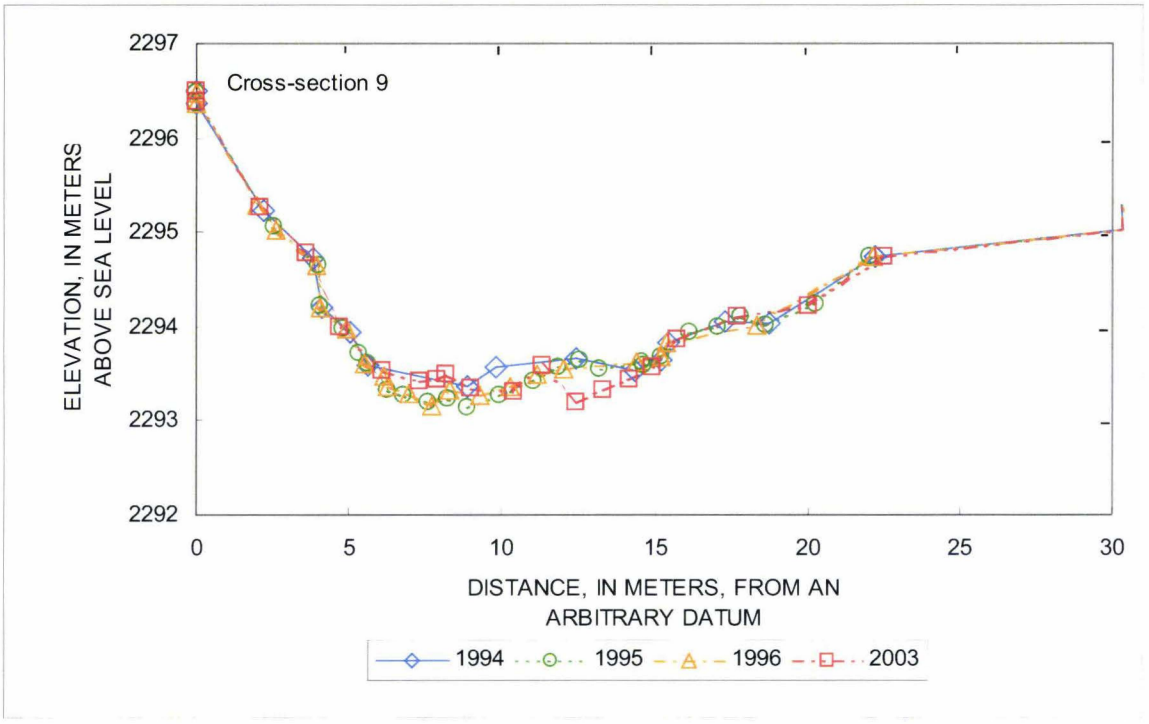


Figure 7. Three cross-sections on the North Fork of the Provo River for a time series between 1994 and 2003. **A.** Cross-section 9, approximately 33 m downstream of log-jam dam. **B.** Cross-section 10, immediately upstream of log-jam dam. **C.** Cross-section 11. Note the significant erosion that took place from 1994 to 1995 in cross-section 9, and the apparent balancing of erosion and deposition processes in this section from 1996 to 2003.

A.



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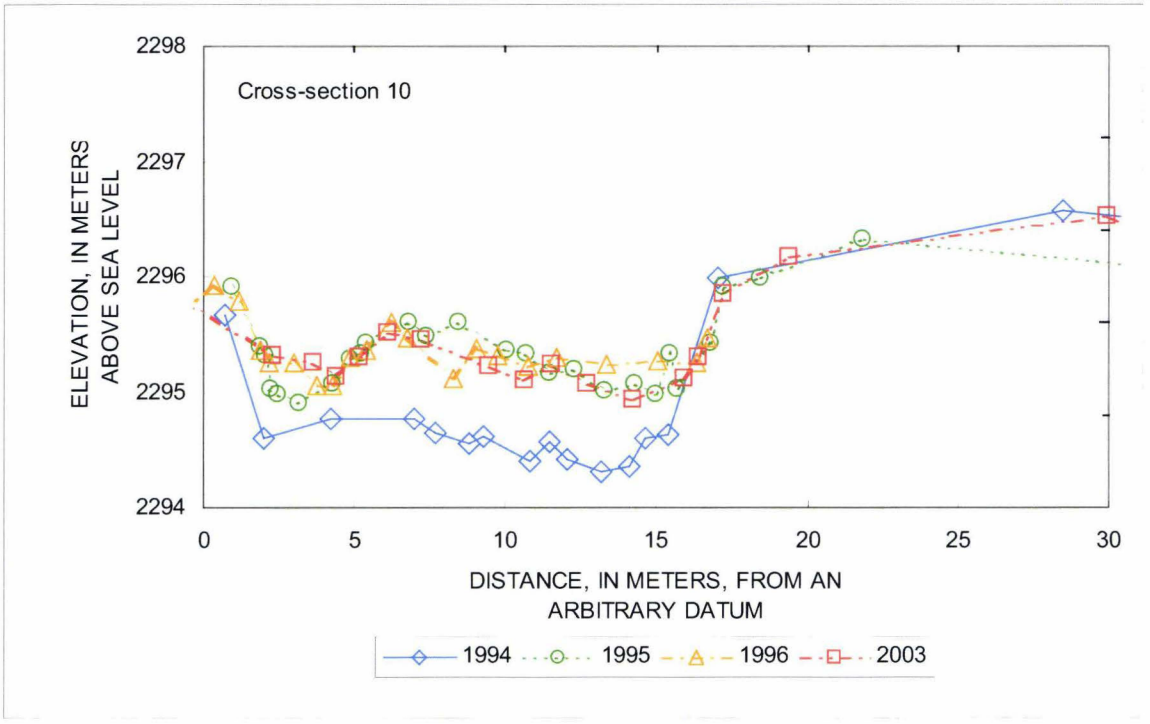


C.

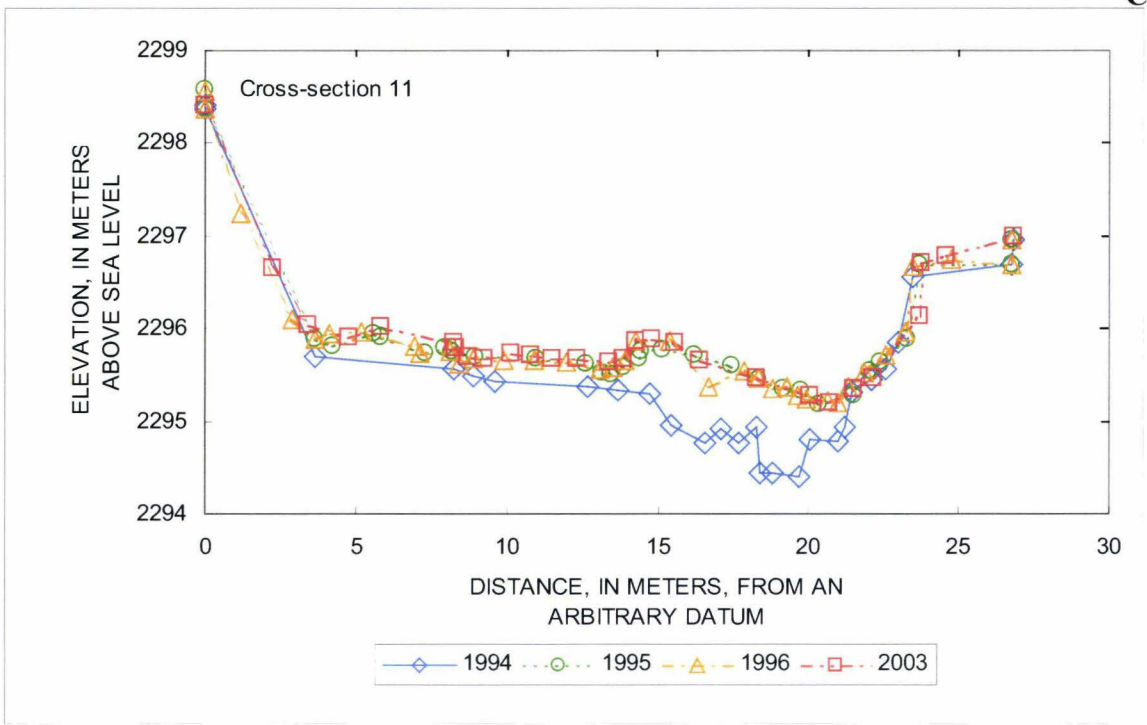
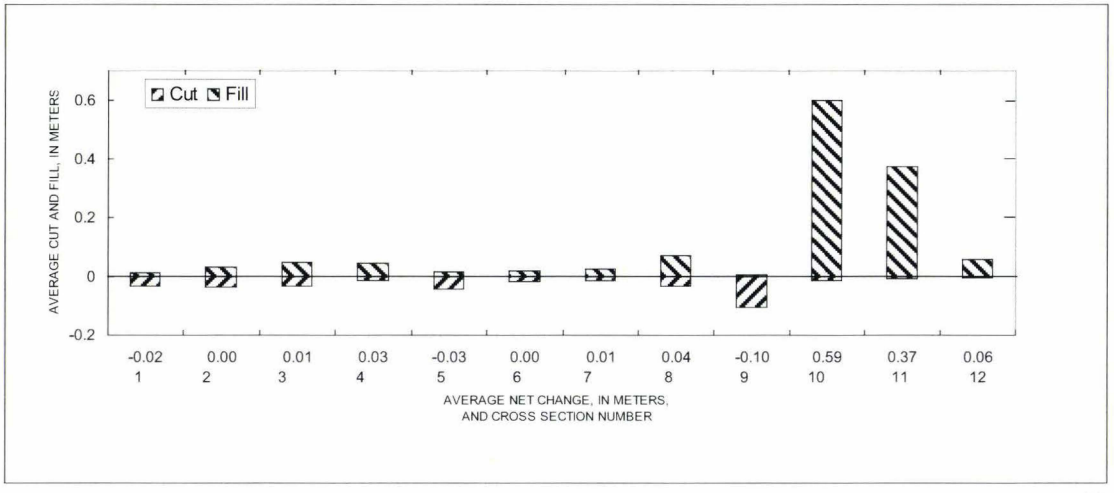
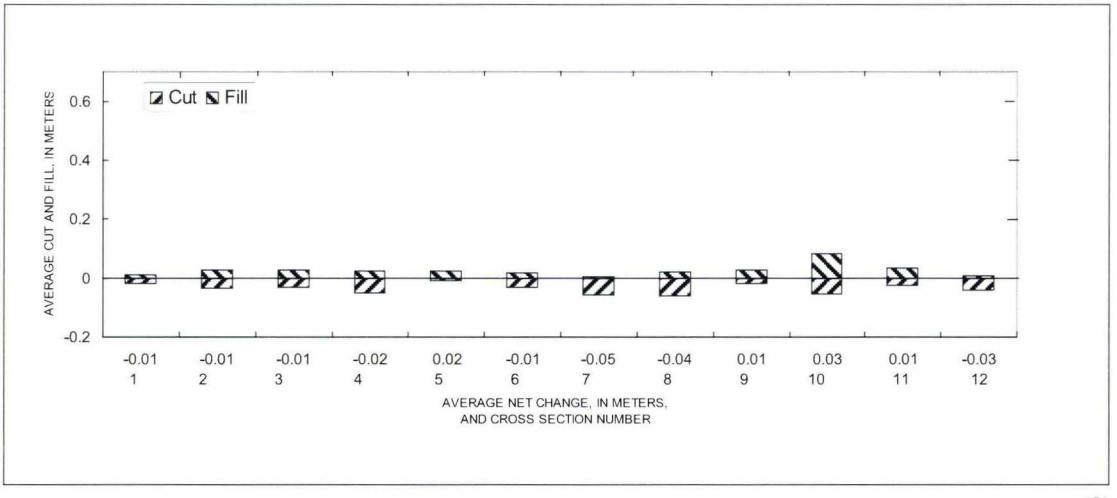

Cross-section 11
ELEVATION, IN METERS ABOVE SEA LEVEL
2299
2298
2297
2296
2295
2294
0
5
10
15
20
25
30
DISTANCE, IN METERS, FROM AN ARBITRARY DATUM
1994
1995
1996
2003

Figure 8. Average cut, fill, and net change values for twelve cross-sections on the North Fork of the Provo River for the period 1994-2003. Values are averaged over each cross-section's width. Cross section #1 is furthest downstream. **A.** From 1994 to 1995. **B.** From 1995 to 1996. **C.** From 1996 to 2003.

A.



B.



C.

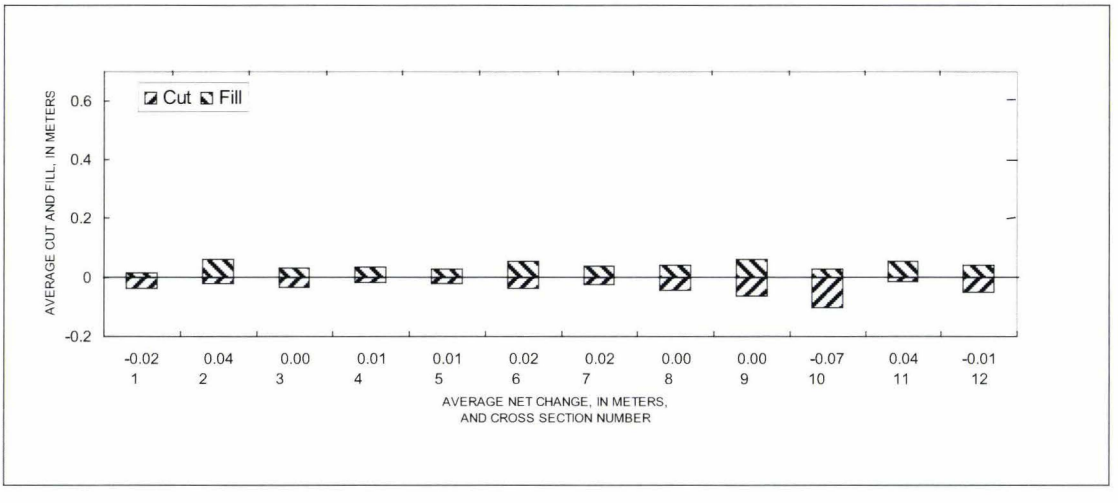
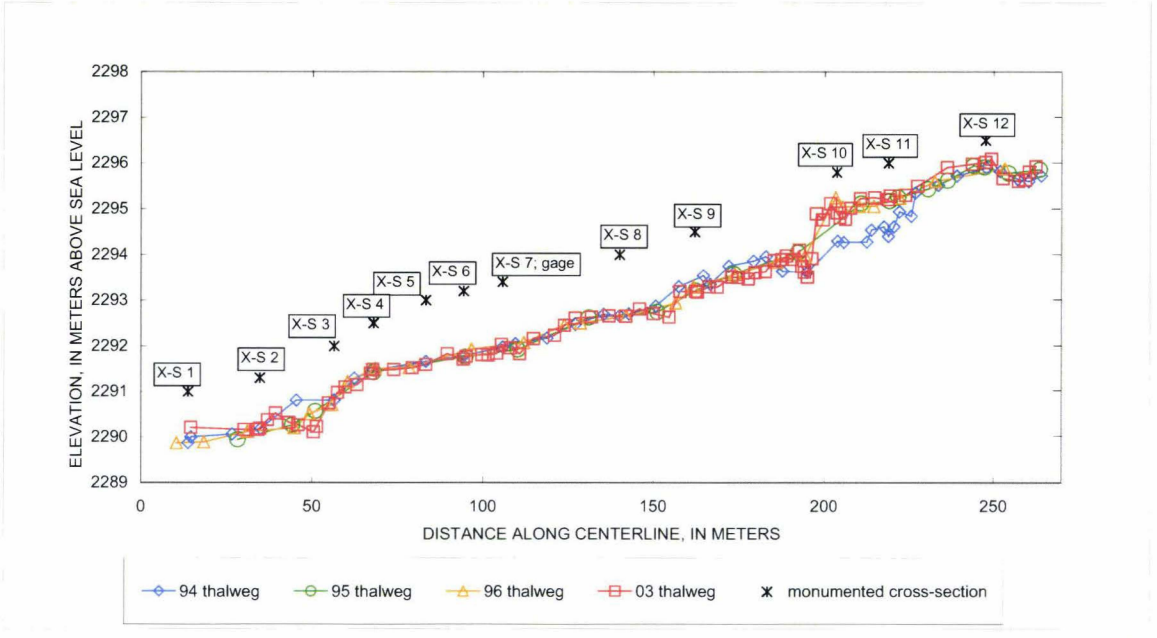
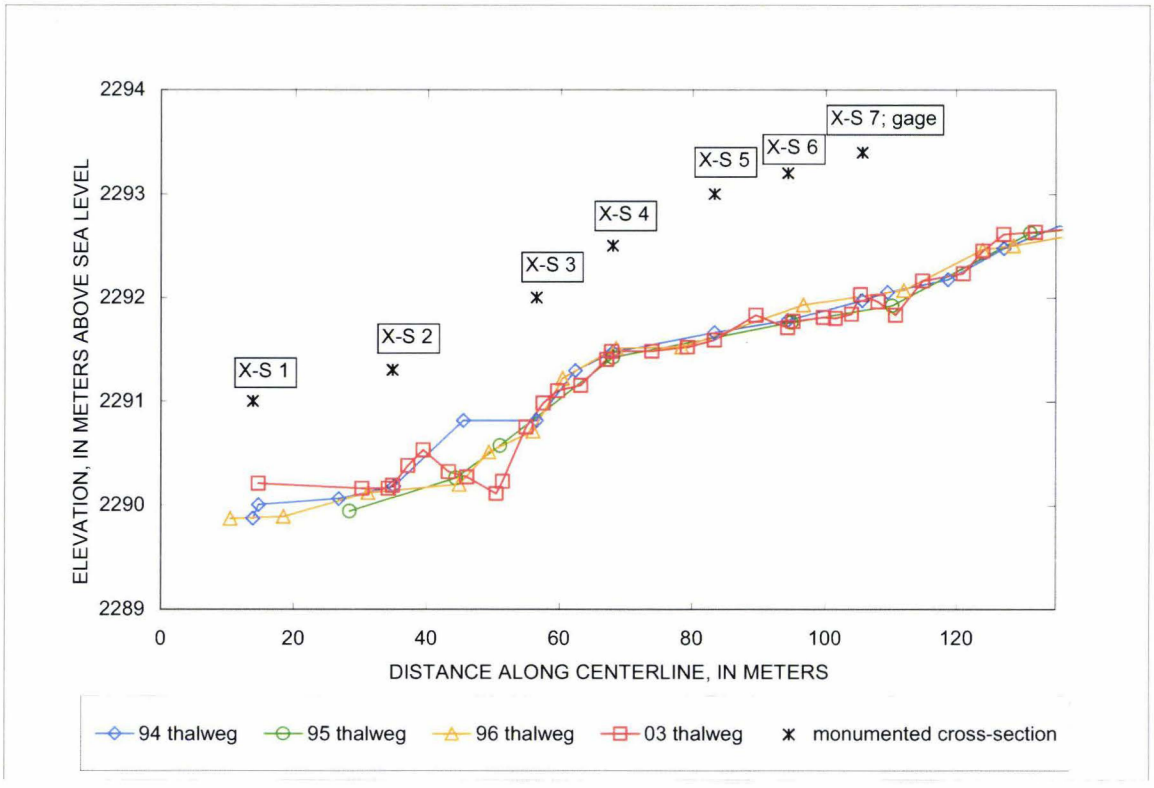


Figure 9. North Fork Provo River longitudinal profile. Four years of data collected at varying flows, show instances of bed elevation adjustment amidst surrounding stable years. **A.** Full long profile. **B.** Lower half. **C.** Upper half.

A.



B.



C.

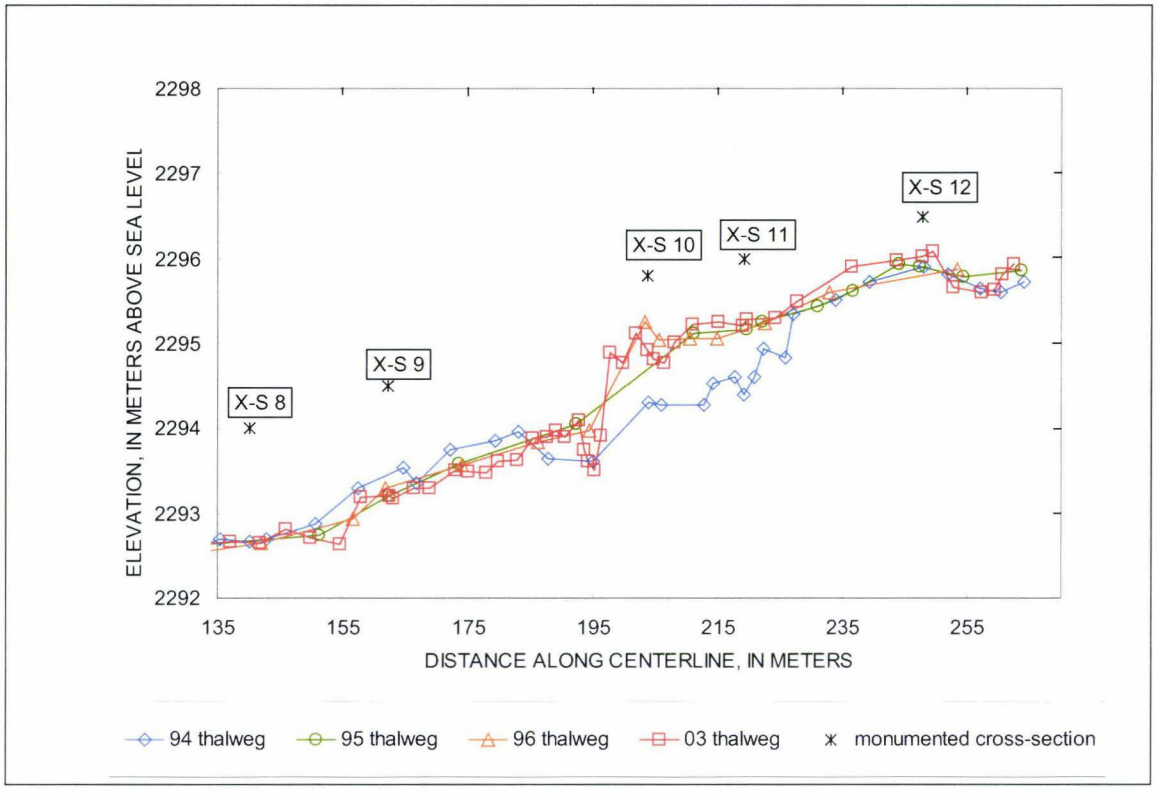
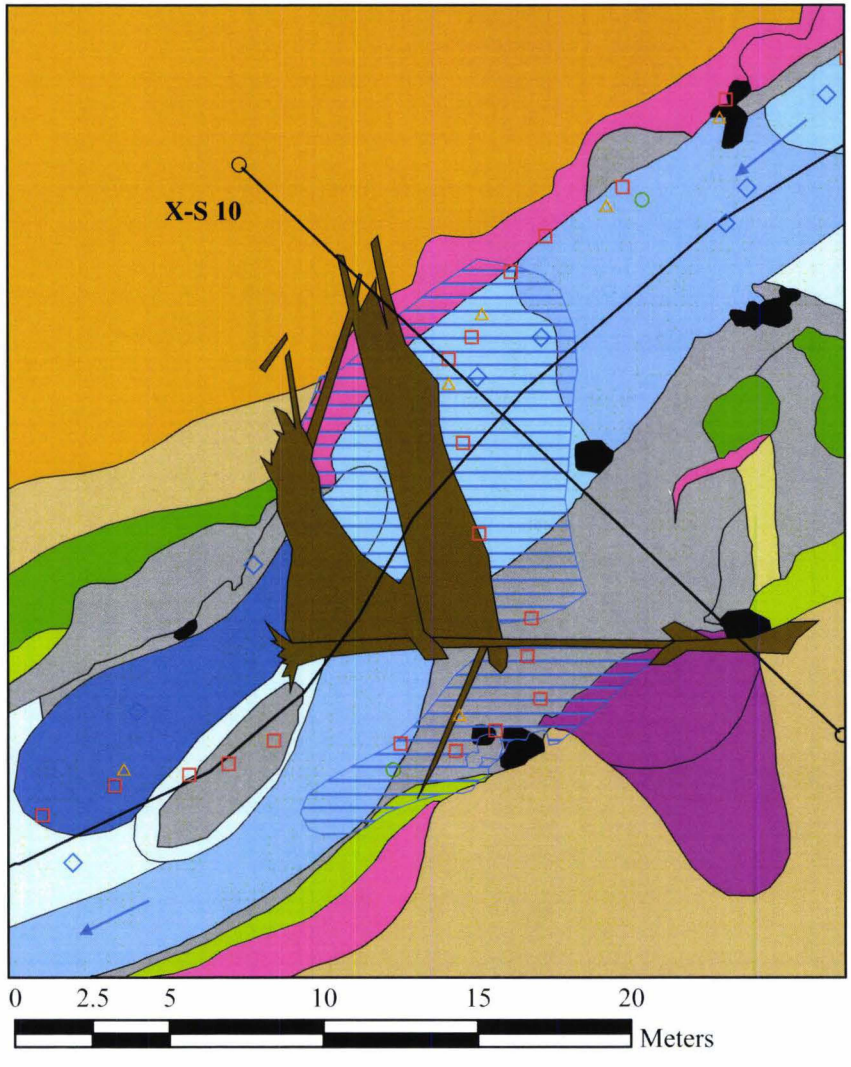
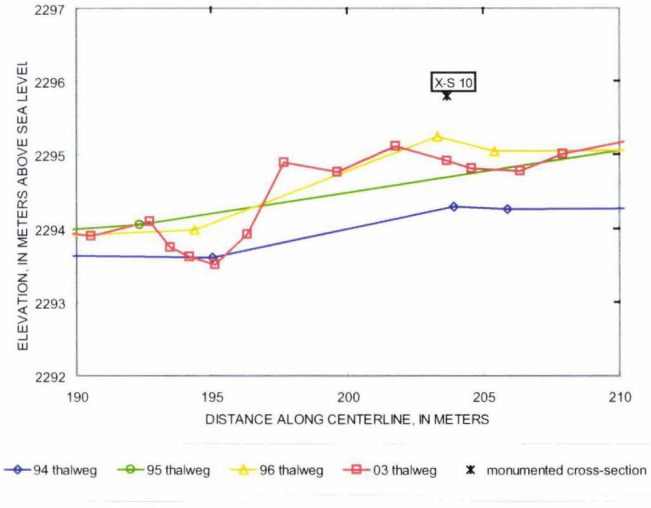

2298
2297
2296
2295
2294
2293
2292
ELEVATION, IN METERS ABOVE SEA LEVEL
135
155
175
195
215
235
255
DISTANCE ALONG CENTERLINE, IN METERS
X-S 8
X-S 9
X-S 10
X-S 11
X-S 12
94 thalweg
95 thalweg
96 thalweg
03 thalweg
monumented cross-section

Figure 10. Mapping and longitudinal profile surveys documented the formation of a plunge pool and scour pool on the North Fork Provo River. The log jam is shown as mapped in 1995 since its status then closely matches that of 2003, and reflects the form responsible for damming sediment. **A.** Detailed mapping shows the formation of a plunge pool just downstream from the log jam dam, while a scour pool formed above the dam following sedimentation in its backwater. **B.** The longitudinal profile surveys suggest that both pools formed between 1996 and 2003.

A.



B.



Thalweg Survey Points

- 1994
- 1995
- 1996
- 2003
- **center line defining distance**
- **Log Jam as Mapped in 1995**
- **New Pools in 2003**
- **Cross-Section**

N (approximate north; surveyed in a local arbitrary coordinate system)

1994 Geomorphic Mapping

- pool
- run
- riffle/step/chute
- gravel flat/submerged bar
- channel margin/bar
- boulders
- inundated by 1.05 yr flood
- inundated by 1.25 yr flood
- high terrace
- slope
- beaver dam remnant
- cutbank
- landslide scarp

Figure 11. Local channel change near a log jam on the North Fork Provo River. **A.** Geomorphic mapping in 1994. **B.** Geomorphic mapping in 1995. **C.** Geomorphic mapping in 2004. **D.** 1994 photography shows the logs spanning the channel but not trapping sediment. **E.** 1995 photography shows the logs functioning as a dam that has trapped sediment. **F.** 2004 photography shows the dam in place with more complexity evident in the features located immediately upstream.

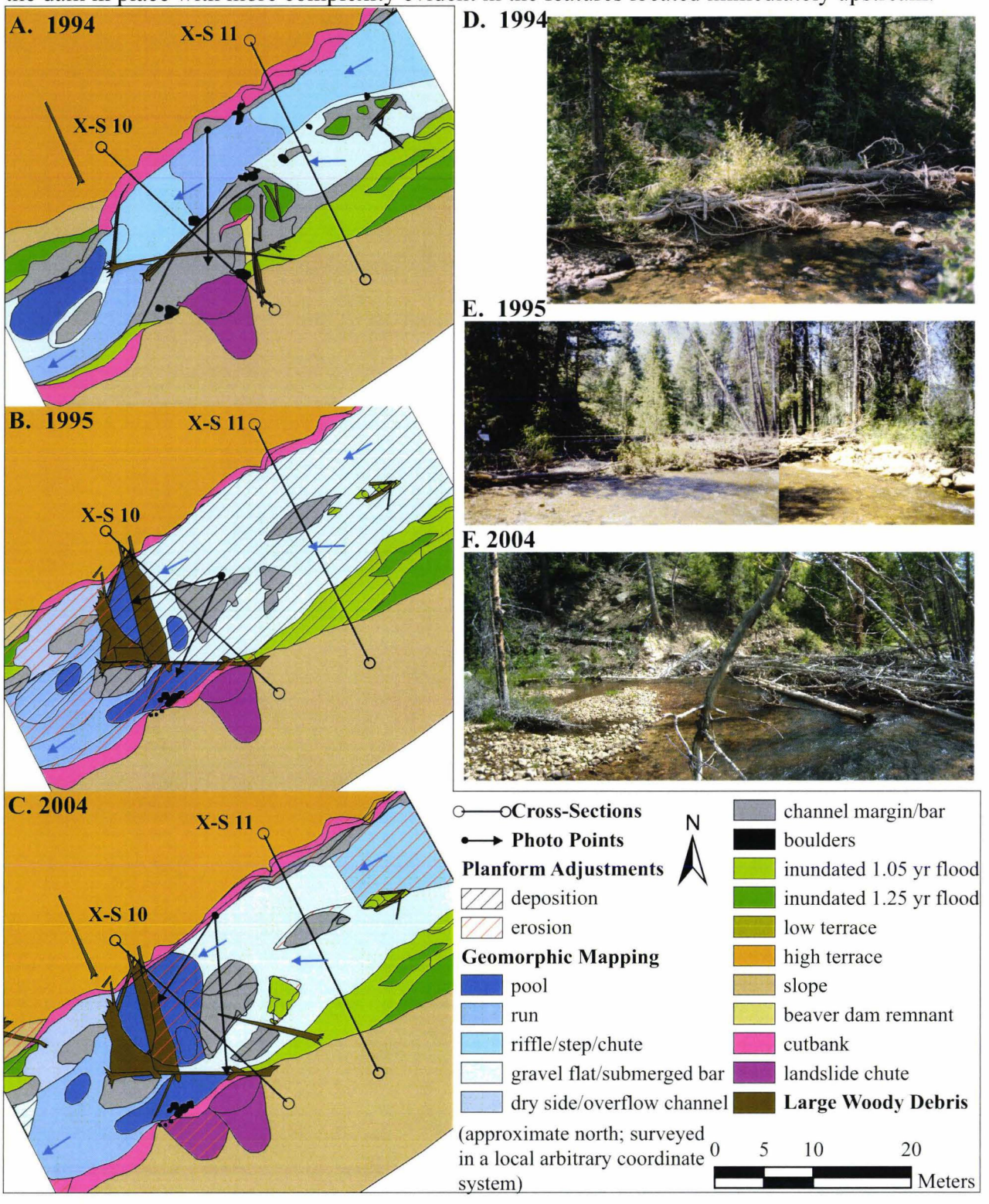


Figure 12. Changes in the region affected by the log-jam formed in the upstream part of the study reach on the North Fork of the Provo River. Size of bed surface substrate obtained from pebble counts conducted in 2003 and 2005 at the same locations as those of 1994.

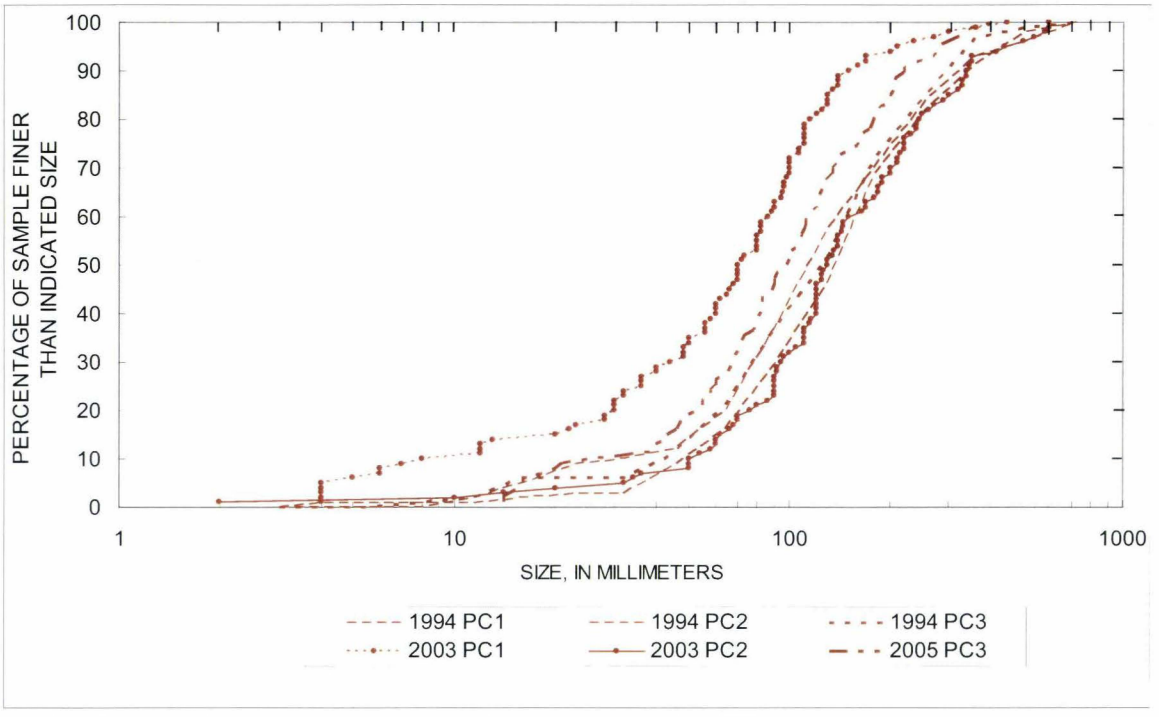


Figure 13. Mapping and longitudinal profile surveys documented the expansion and deepening of a scour pool and augmentation of a downstream riffle on the North Fork Provo River. **A.** Detailed mapping shows planimetric changes in the organization of this segment of channel. **B.** The longitudinal profile surveys suggest that most of these changes took place between 1996 and 2003.

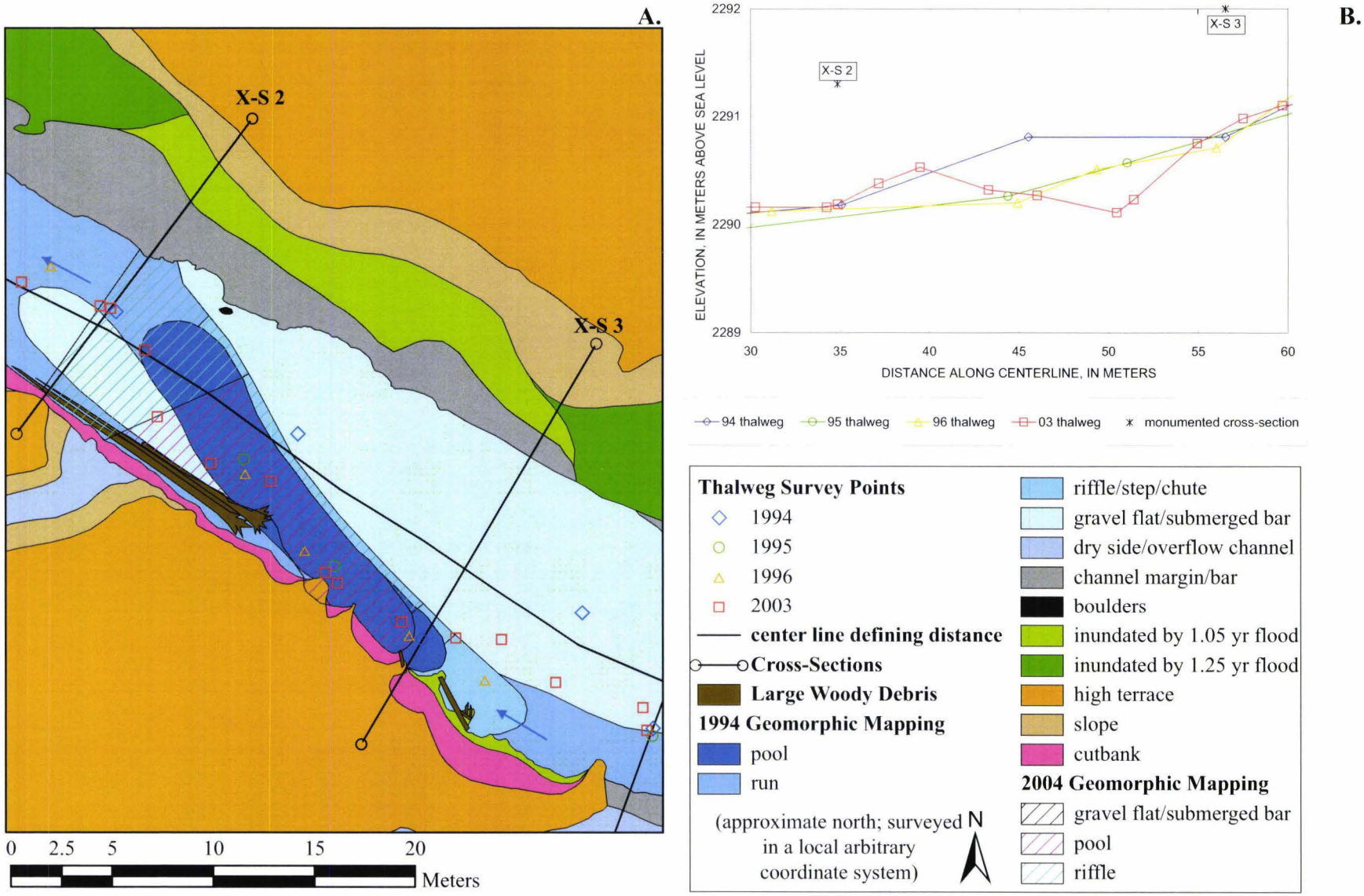
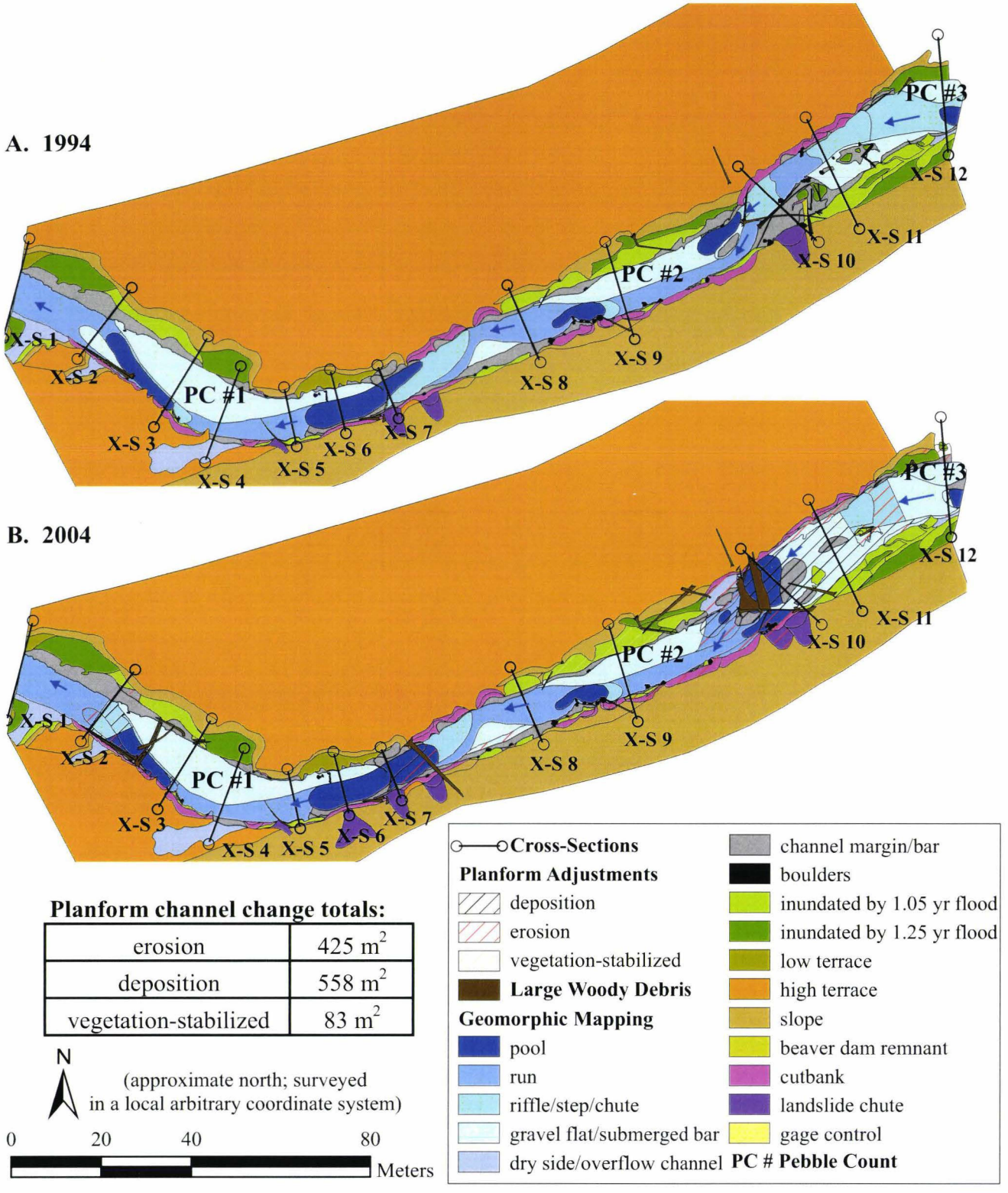


Figure 14. Planimetric channel changes on the North Fork Provo River. **A.** Geomorphic mapping in 1994. **B.** Geomorphic mapping in 2004 is based on a 2003 channel survey at which time the mean daily flow was approximately 5.7 m^3/s; the mapped water's edge reflects this flow. The active channel (defined by all channel features below the 1.25-year floodplain level) is an average of 13.9 m wide.



Planform channel change totals:

erosion	425 m^2
deposition	558 m^2
vegetation-stabilized	83 m^2

Figure 15. Lake Fork River monitoring reach. Simple geomorphic map of the study area that shows the general geologic setting and channel patterns (Stamp 1997).

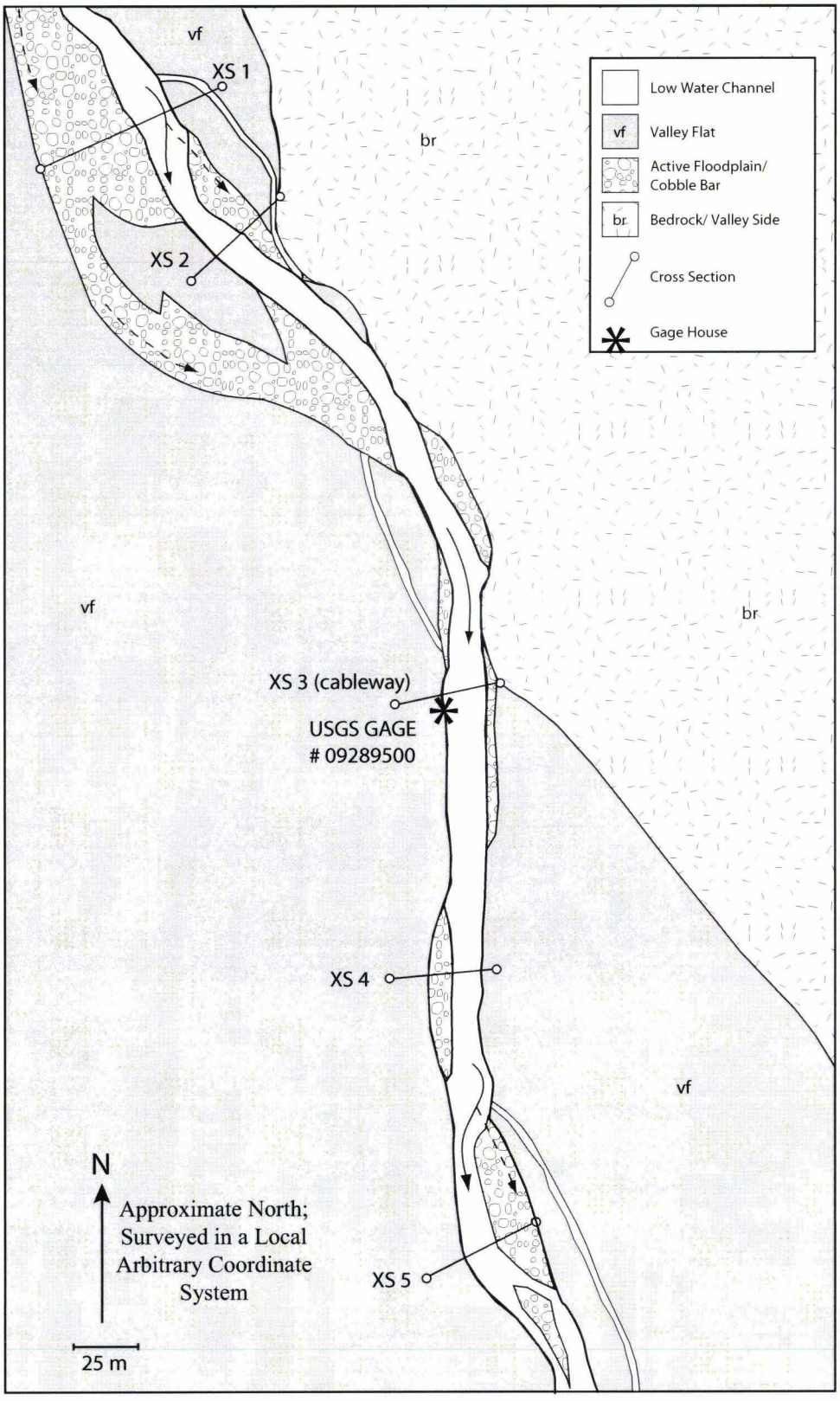


Figure 16. Average cut, fill, and net change values for five cross-sections on the Lake Fork River above Moon Lake for the period 1997-2003. Values are averaged over each cross-section's width. Cross section #1 is furthest downstream.

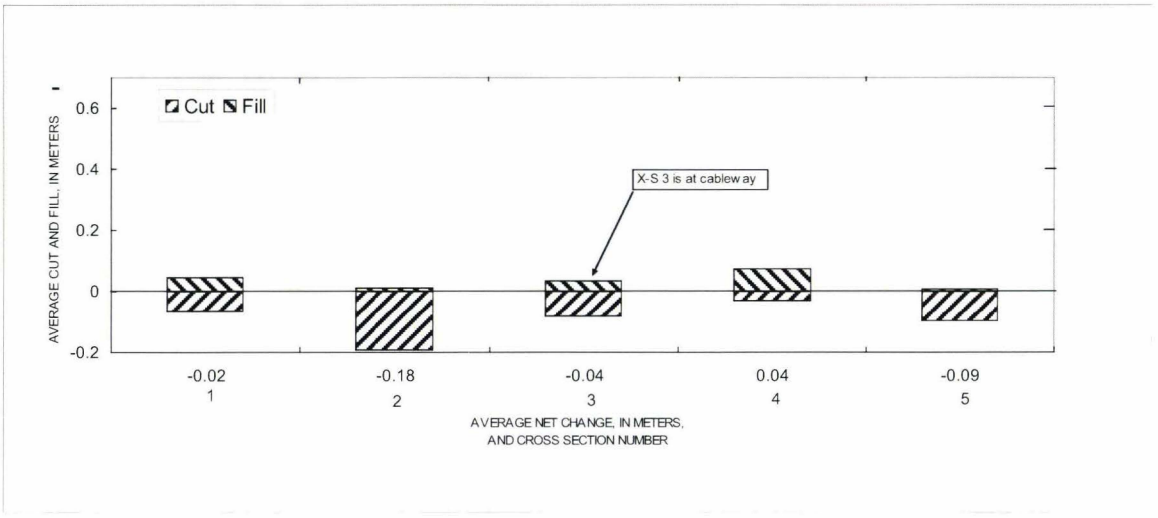
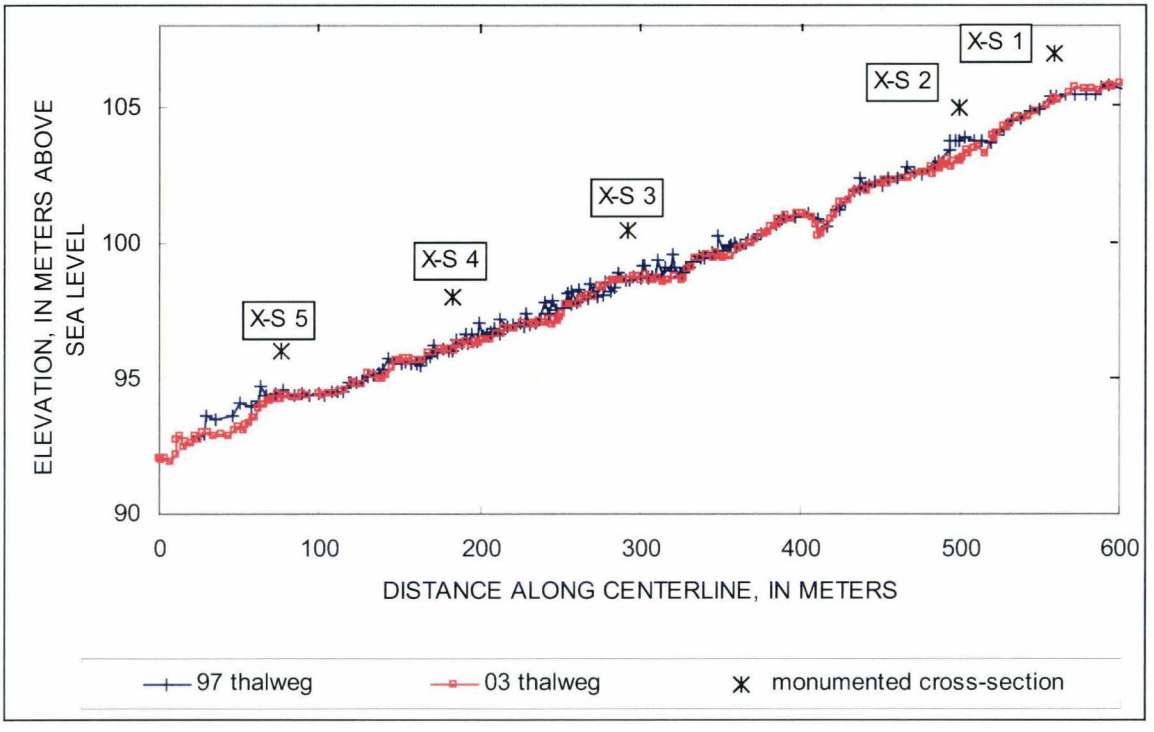
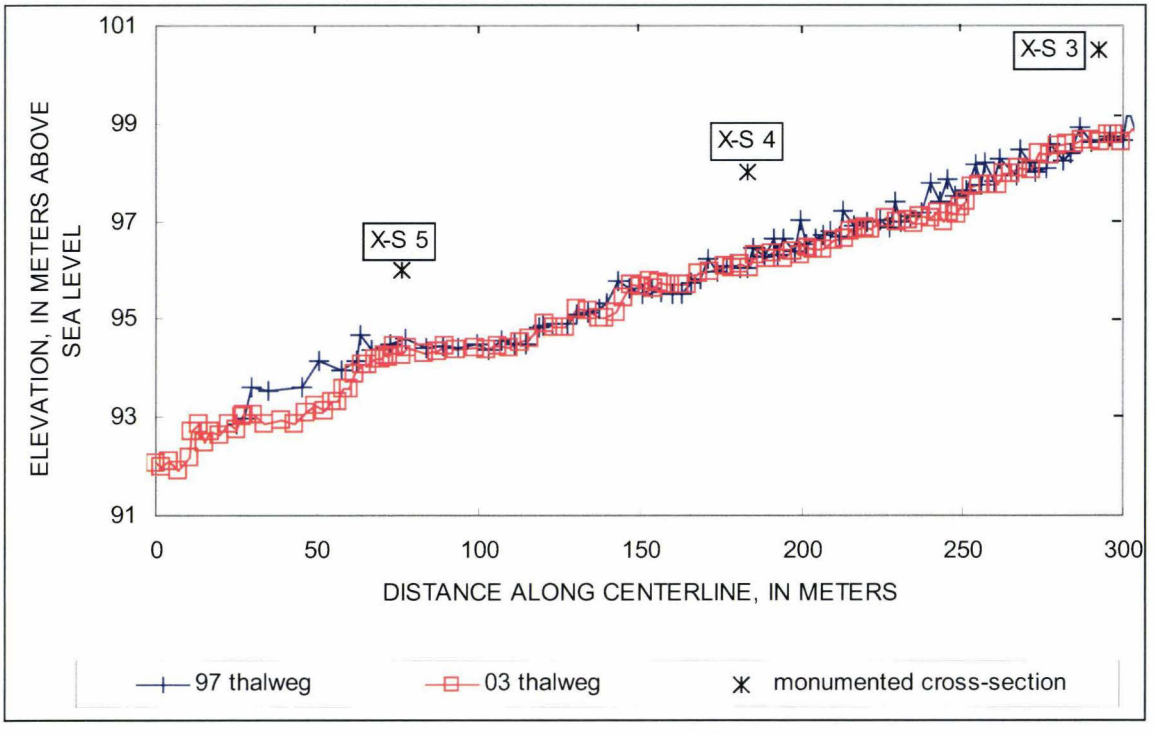


Figure 17. Longitudinal profile for the Lake Fork River above Moon Lake study reach. Two years of data collected at varying flows, show instances of thalweg erosion for the period 1997-2003. **A.** Full long profile. **B.** Lower half. **C.** Upper half.

A.



B.



C.

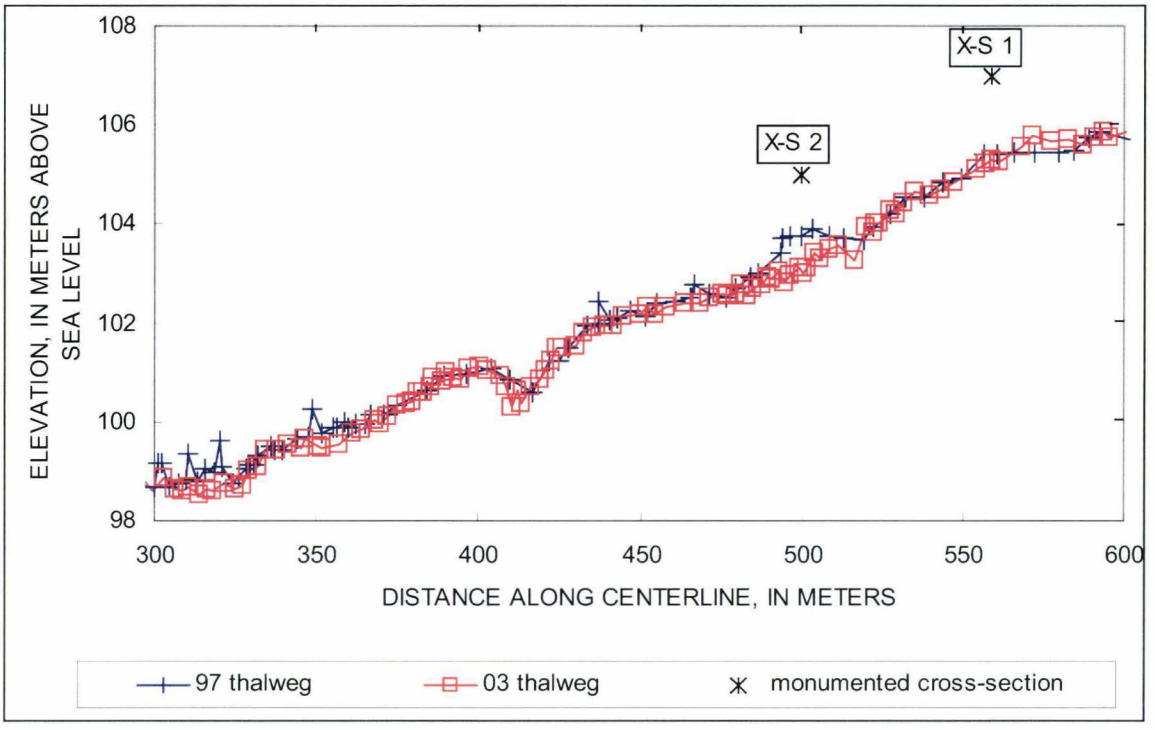

108
106
104
102
100
98
300
350
400
450
500
550
600
ELEVATION, IN METERS ABOVE SEA LEVEL
DISTANCE ALONG CENTERLINE, IN METERS
X-S 1
X-S 2
97 thalweg
03 thalweg
monumented cross-section

Figure 18. A cross-section, longitudinal profile, and map of a section of the Lake Fork River study reach. **A.** The planform mapping in this area only identified a portion of the erosion that took place, a change in classification from a riffle to a run (see figure 20). **B.** Cross-section 2 shows that scour took place across most of the main channel. **C.** The longitudinal profile showd that the scour took place up- and downstream from X-S 2, and extended upstream from the new run identified in 2004 planform mapping.

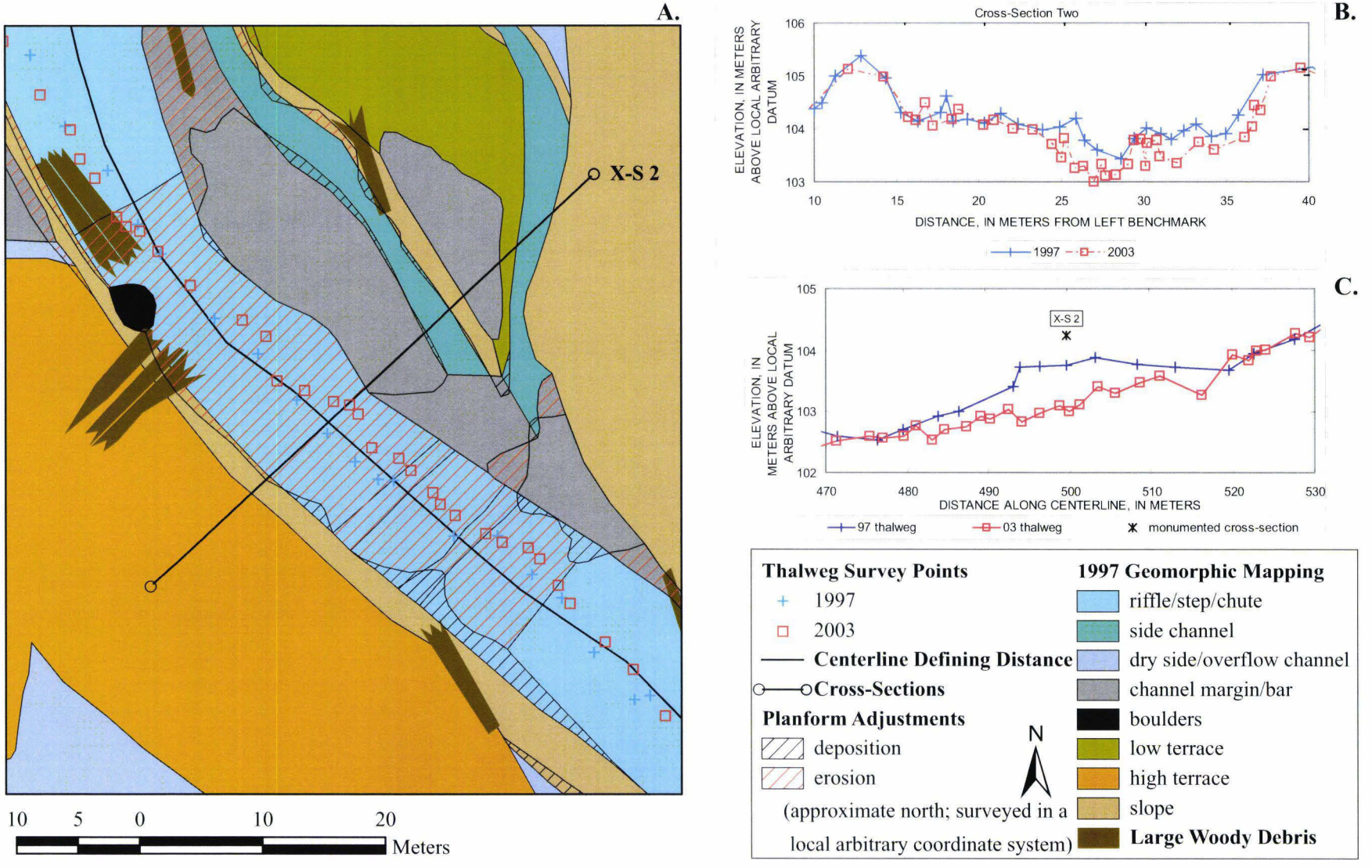


Figure 19. A section of planform mapping and longitudinal profile in the Lake Fork River study reach. **A.** The planform mapping in this area documented bank erosion, mid-channel bar expansion, and overflow channel expansion. **B.** The placement of thalweg survey points supports both the bank erosion documented by planform mapping and the in-channel erosion in the center of **A**.

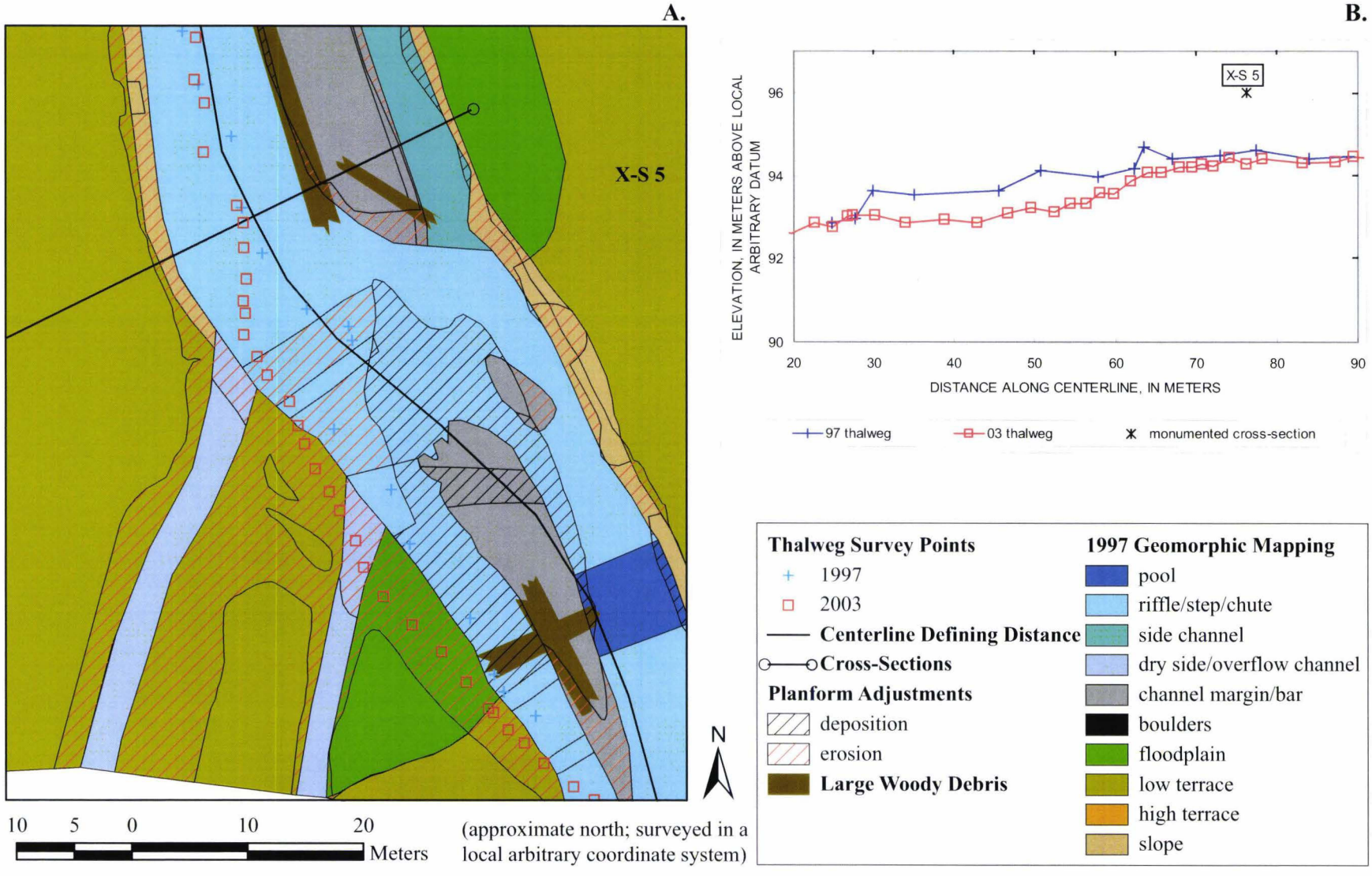


Figure 20. Two years of planform mapping for the Lake Fork River study reach. **A.** Geomorphic mapping from 1997 produced at an original scale of 1" = 25 m. **B.** 2004 mapping was produced by updating the 1997 maps at a scale of 1" = 15 m. The 2004 active channel was an average of 29 m wide, and a total of 17,172 m^2 in area.

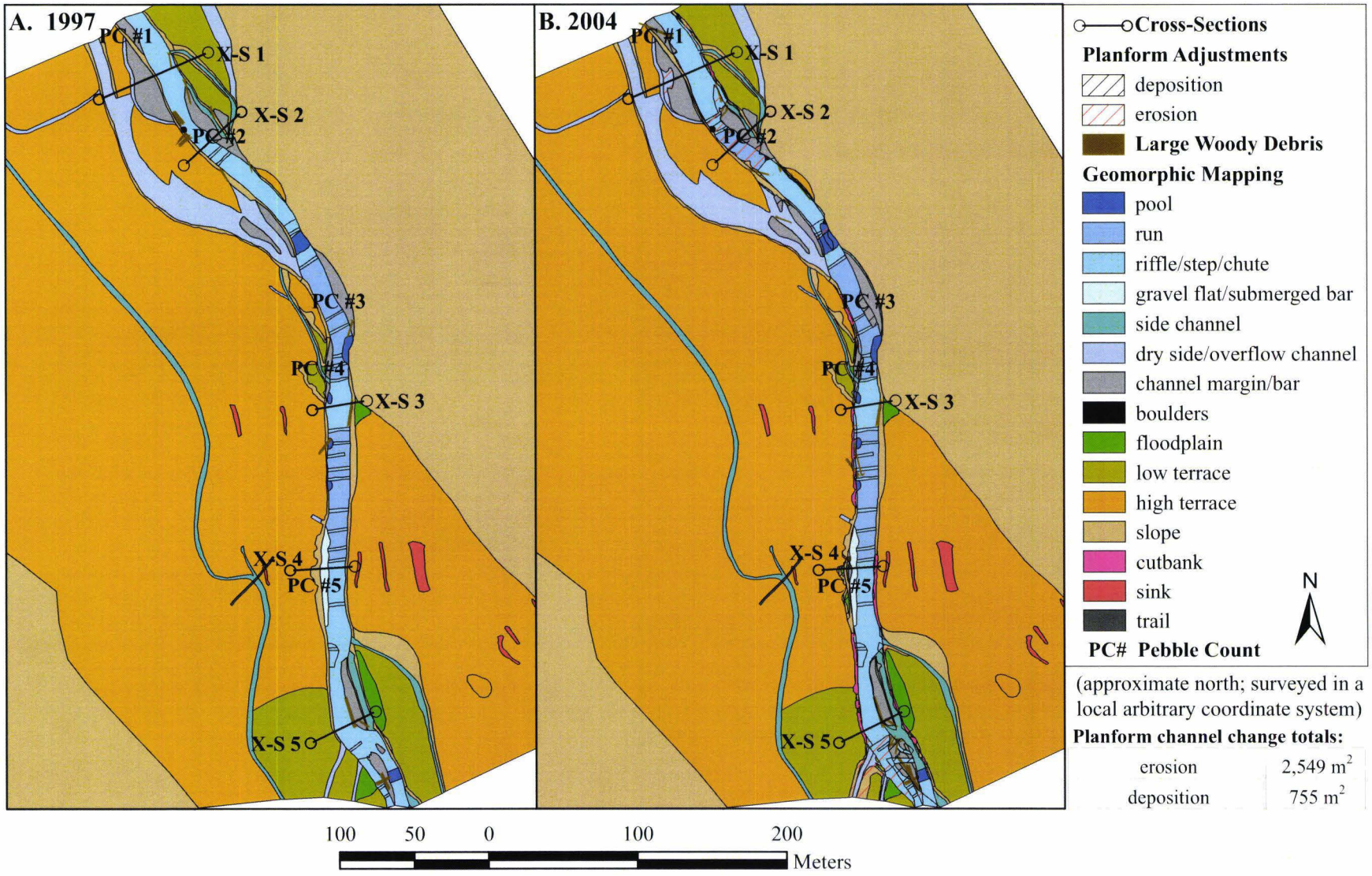


Figure 21. Bed surface substrate measurements for five pebble count sites for the Lake Fork River above Moon Lake. Samples were collected from active depositional zones in 2005.

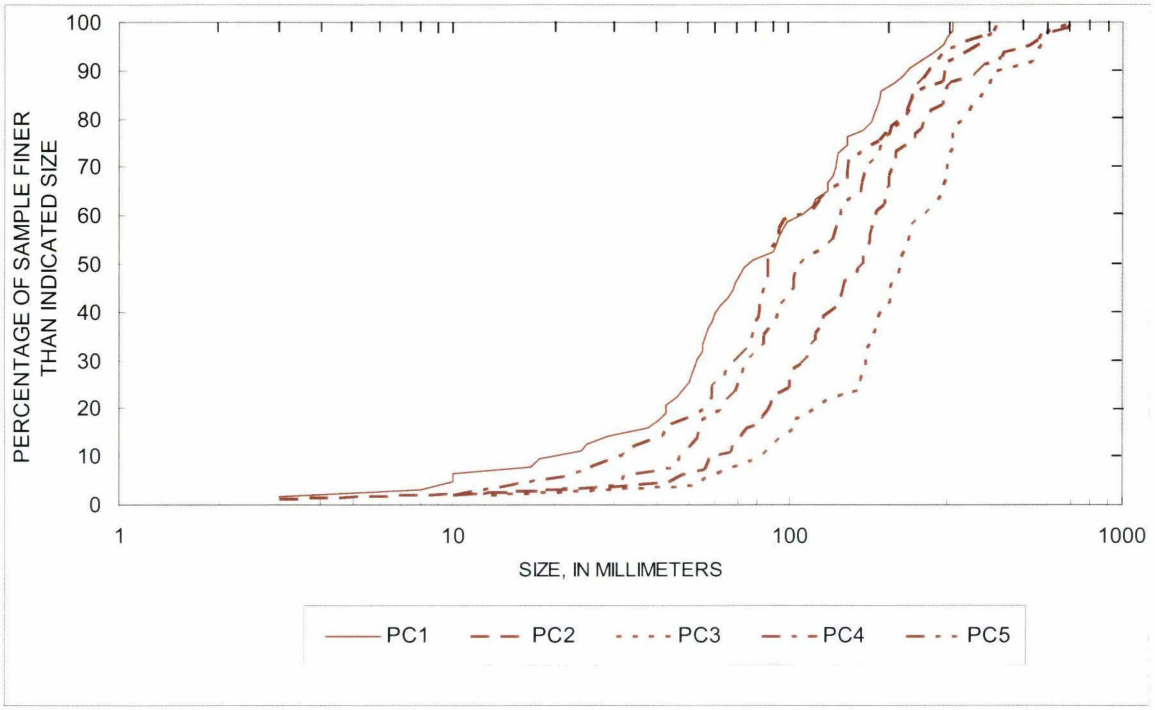
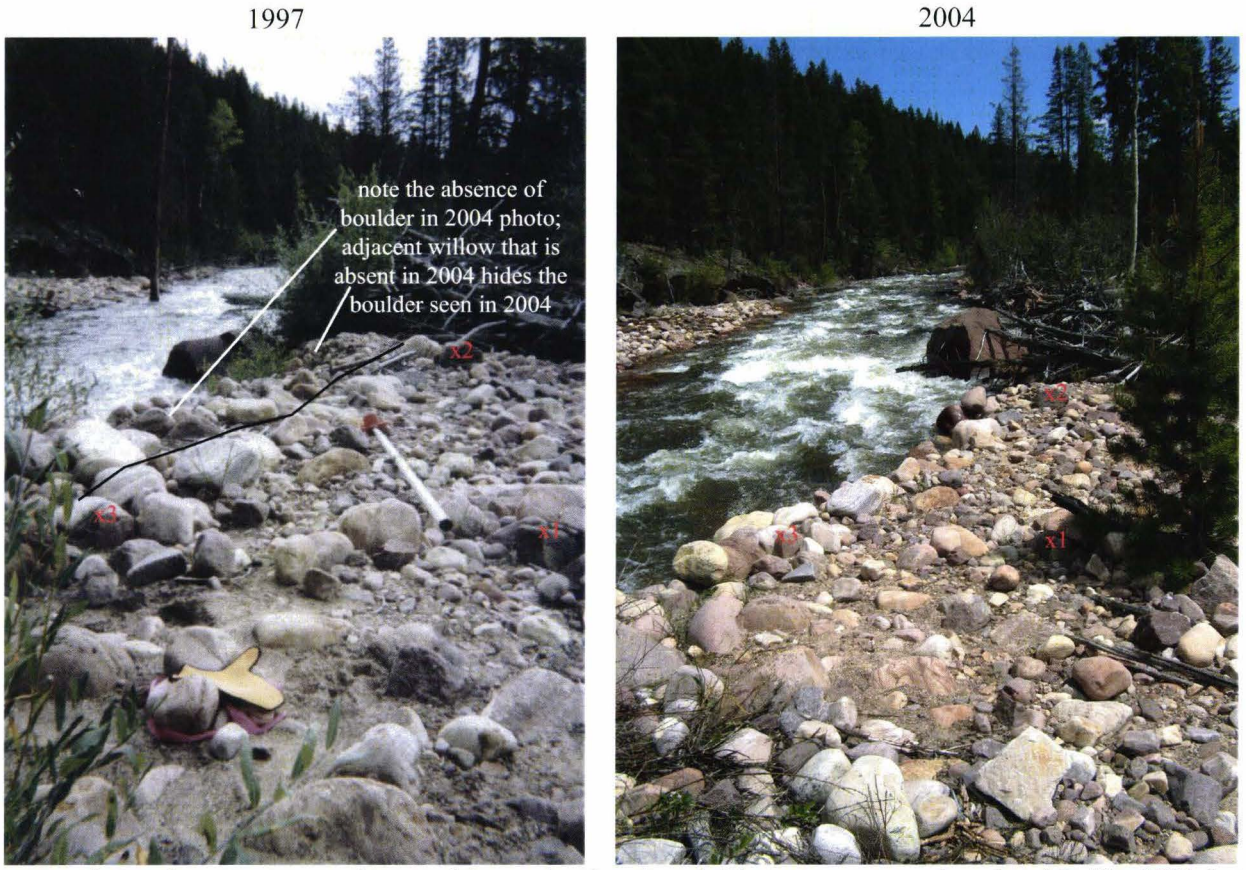


Figure 22. Photographic evidence documented changes in the Lake Fork River that would have gone undetected using only the quantitative methods described in this paper **A.** At benchmark 6. **B.** Near benchmark 3.

A.



Photos are facing downstream near the top of the reach at benchmark 6 between cross-sections 1 and 2. The 2004 shot is taken approximately 3 meters upstream from the 1997 photo location. Red "Xs" are match points included for reference, while the black line on the 1997 photo shows the approximate location of the 2004 bank/terrace edge.

B.

Photos are facing across the channel from river right near bewnchmark 3 and cross-section 4. The wetted channel is approximately 17 meters wide at this location.

Figure 23. Rock Creek monitoring reach. Simple geomorphic map of the study site that shows the general geomorphic setting and the channel patterns (Smelser 1997).

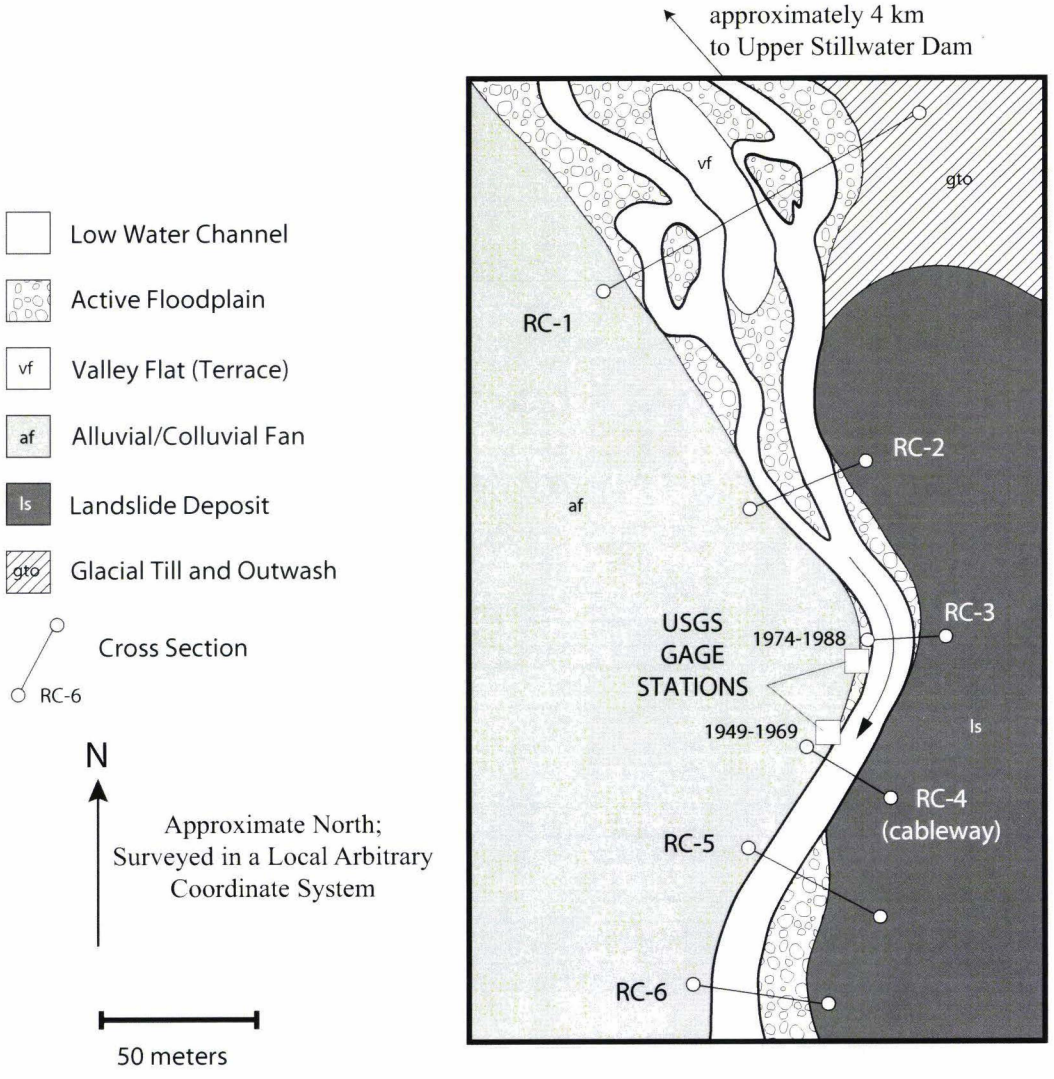
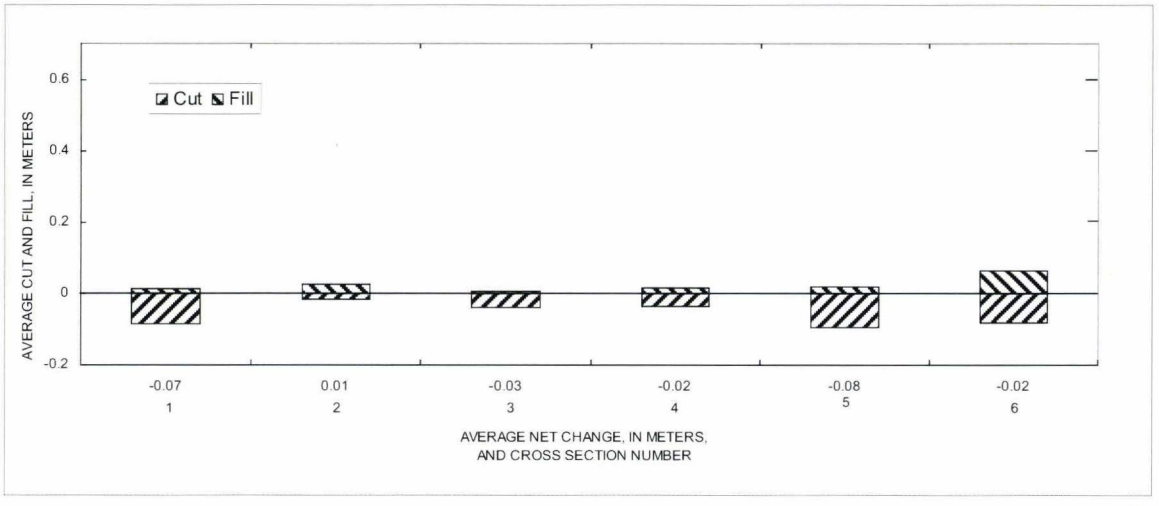


Figure 24. Average cut, fill, and net change values for six cross-sections on the Rock Creek for the period 1995-2003. Values are averaged over each cross-section's width. Cross section #1 is furthest downstream. **A.** From 1995 to 1996. **B.** From 1996 to 2003.

A.



B.

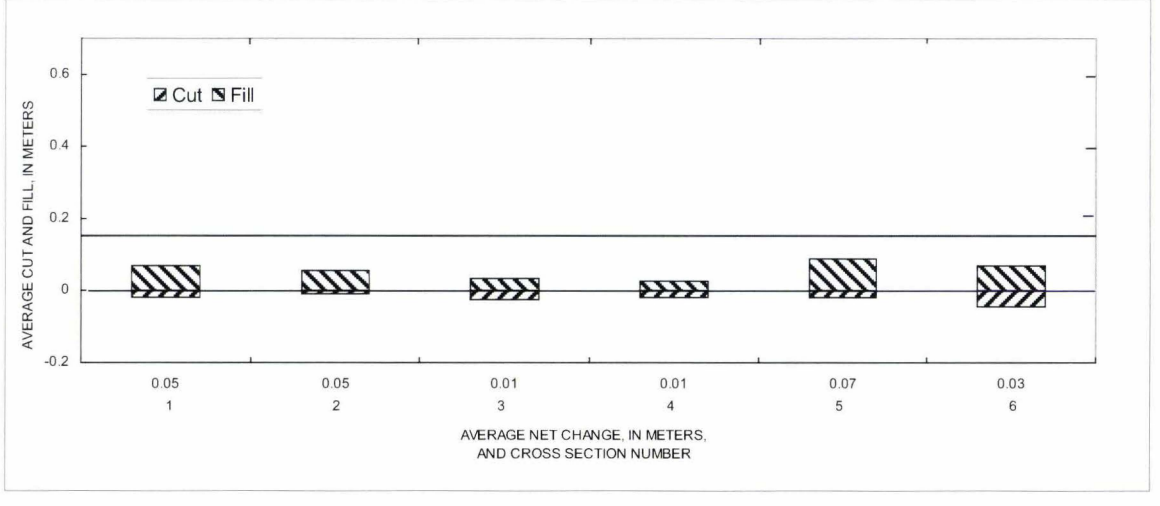
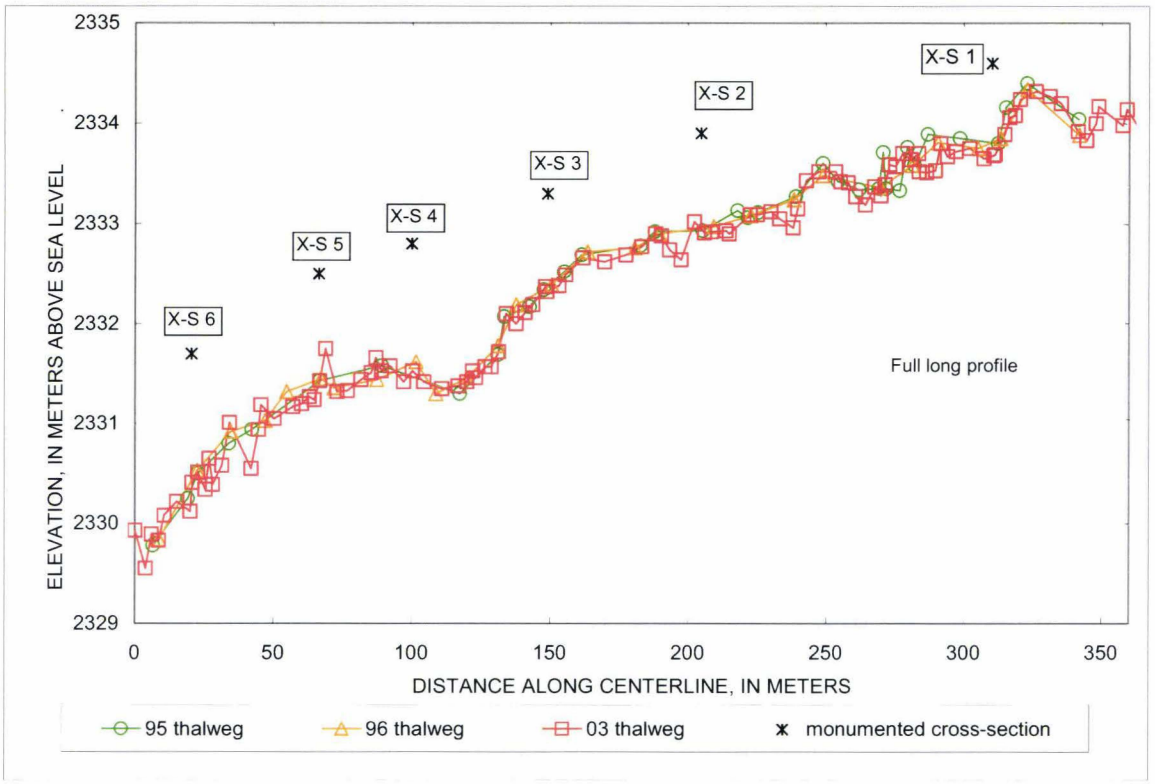
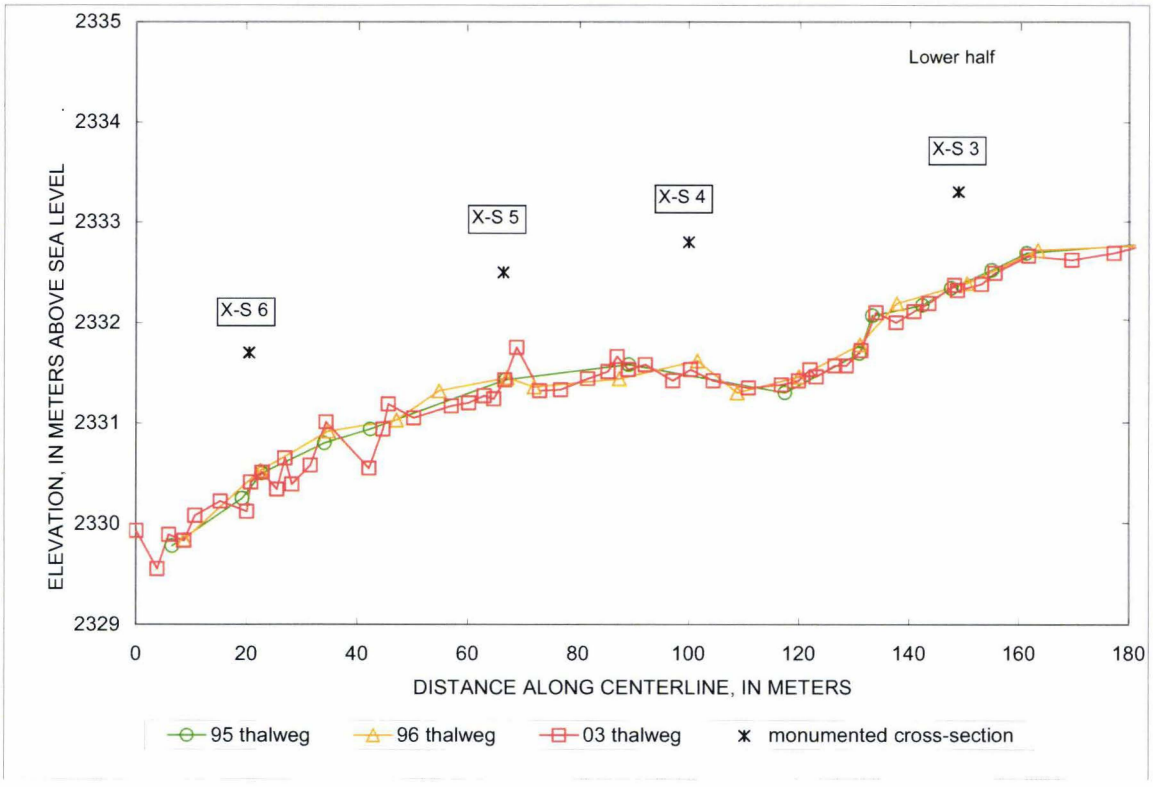


Figure 25. Longitudinal profile for Rock Creek study site. Three years of data collected at varying flows during the period 1995-2003. **A.** Full long profile. **B.** Lower half. **C.** Upper half.

A.



B.



C.

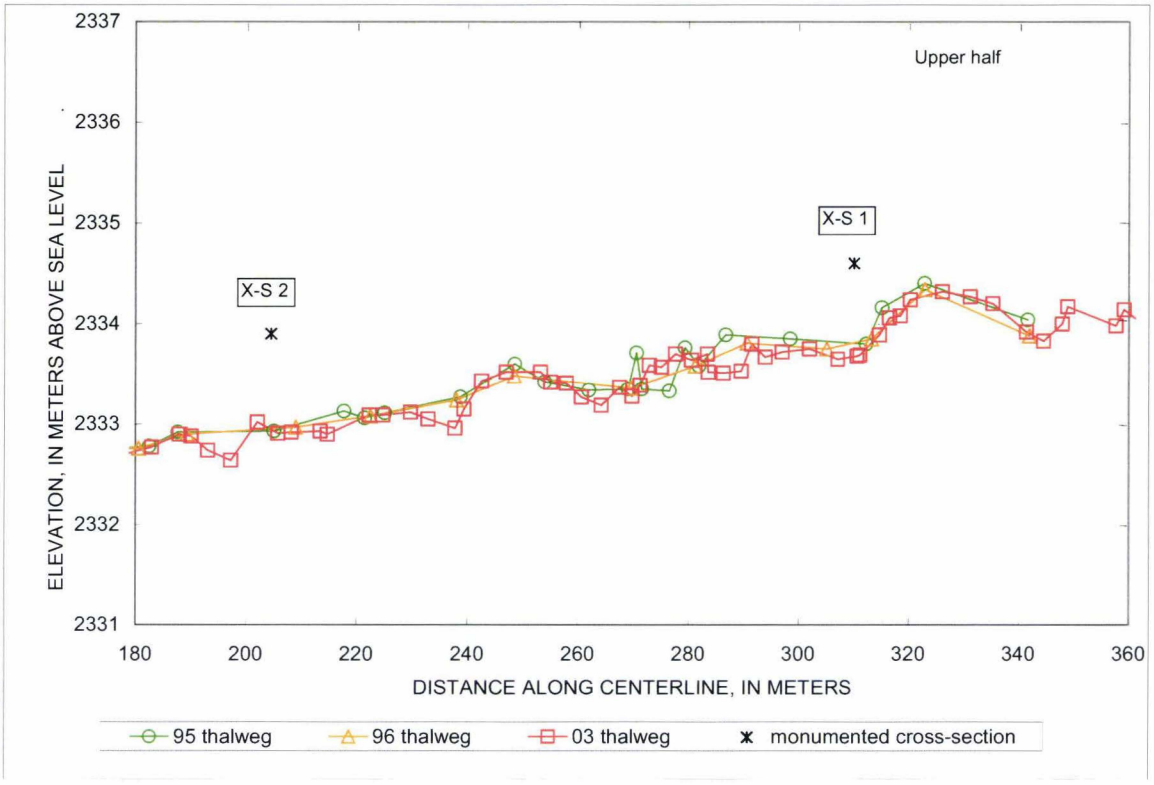
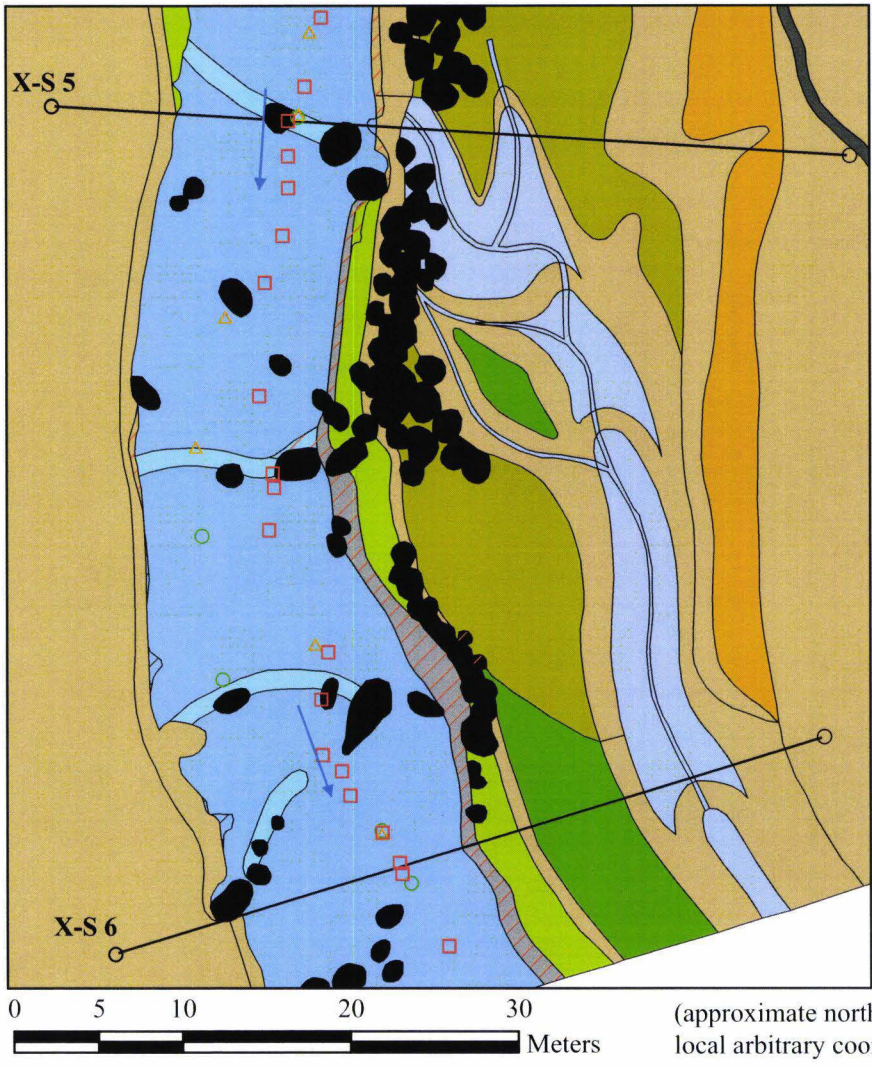

Upper half
X-S 1
X-S 2
ELEVATION, IN METERS ABOVE SEA LEVEL
2337
2336
2335
2334
2333
2332
2331
180
200
220
240
260
280
300
320
340
360
DISTANCE ALONG CENTERLINE, IN METERS
95 thalweg
96 thalweg
03 thalweg
monumented cross-section

Figure 26. Planform mapping and longitudinal profile survey of a downstream section of the Rock Creek study reach. **A.** The planform mapping allows observation of the horizontal position of thalweg survey points, and identifies the in-channel forms present during 1995; planform changes were limited to a small amount of bank erosion. **B.** The longitudinal profile suggests that a series of pools and a boulder step were formed between survey years, but the difference in survey point density and placement between 2003, and the other two years likely accounts for this apparent change.

A.



B.

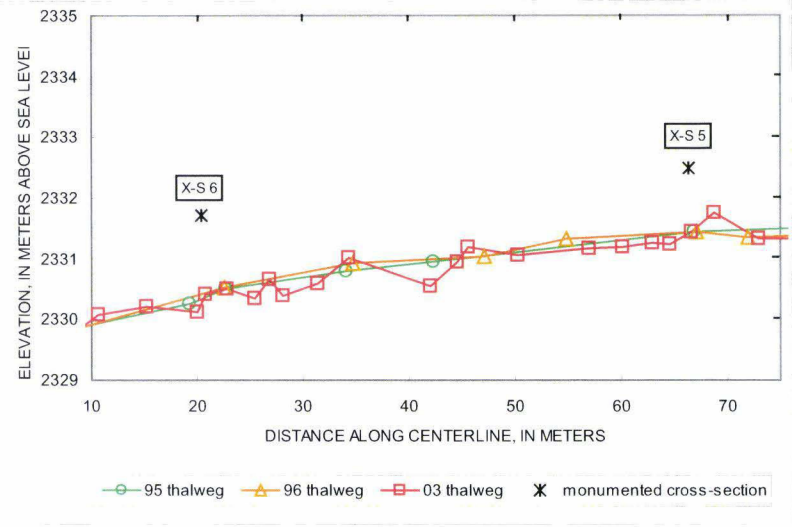


Figure 27. Planform mapping and longitudinal profile survey of an upstream section of the Rock Creek study reach. **A.** The planform mapping allows observation of the horizontal position of thalweg survey points, and identifies the in-channel forms present during 1995; planform changes included lateral bank adjustments and in-channel adjustments. **B.** The longitudinal profile suggests a number of adjustments. The upstream area in the black circle on the map coincides with a case of apparent scour and immediate downstream sedimentation; while the apparent scour is likely actual change, the apparent sedimentation may be the result of a difference in survey point placement. The two downstream areas in red circles, coincide with cases of apparent scour on the profile, but these observations likely represent an increase in survey point density in 2003.

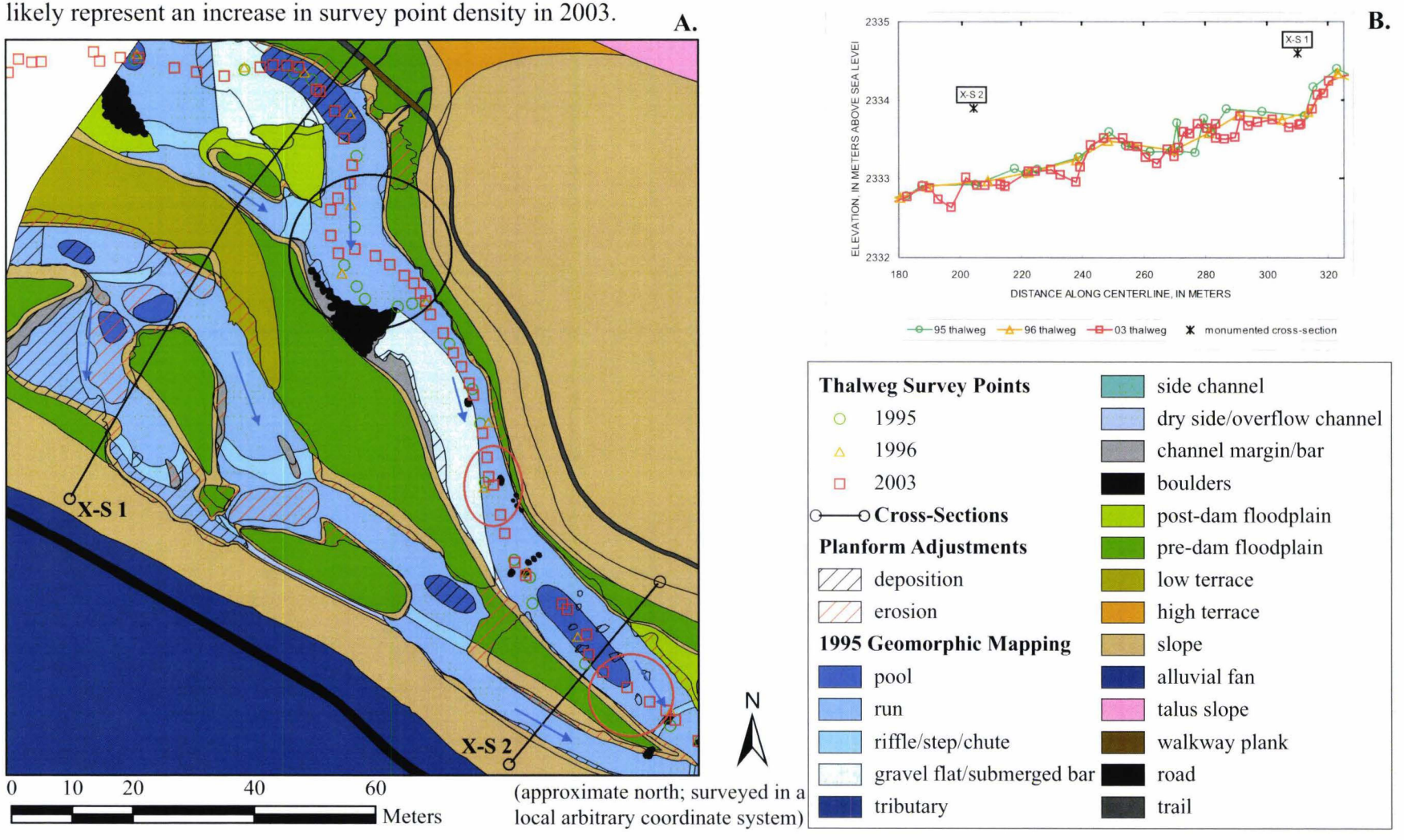


Figure 28. Planform mapping for the Rock Creek study reach. **A.** Geomorphic mapping from 1995. **B.** Geomorphic mapping from 2004 and channel changes between the two years' mapping data. The active channel (defined by all features below the post-dam floodplain level) in 2004 was an average of 18.1 m wide and took up a total of 6,005 m^2.

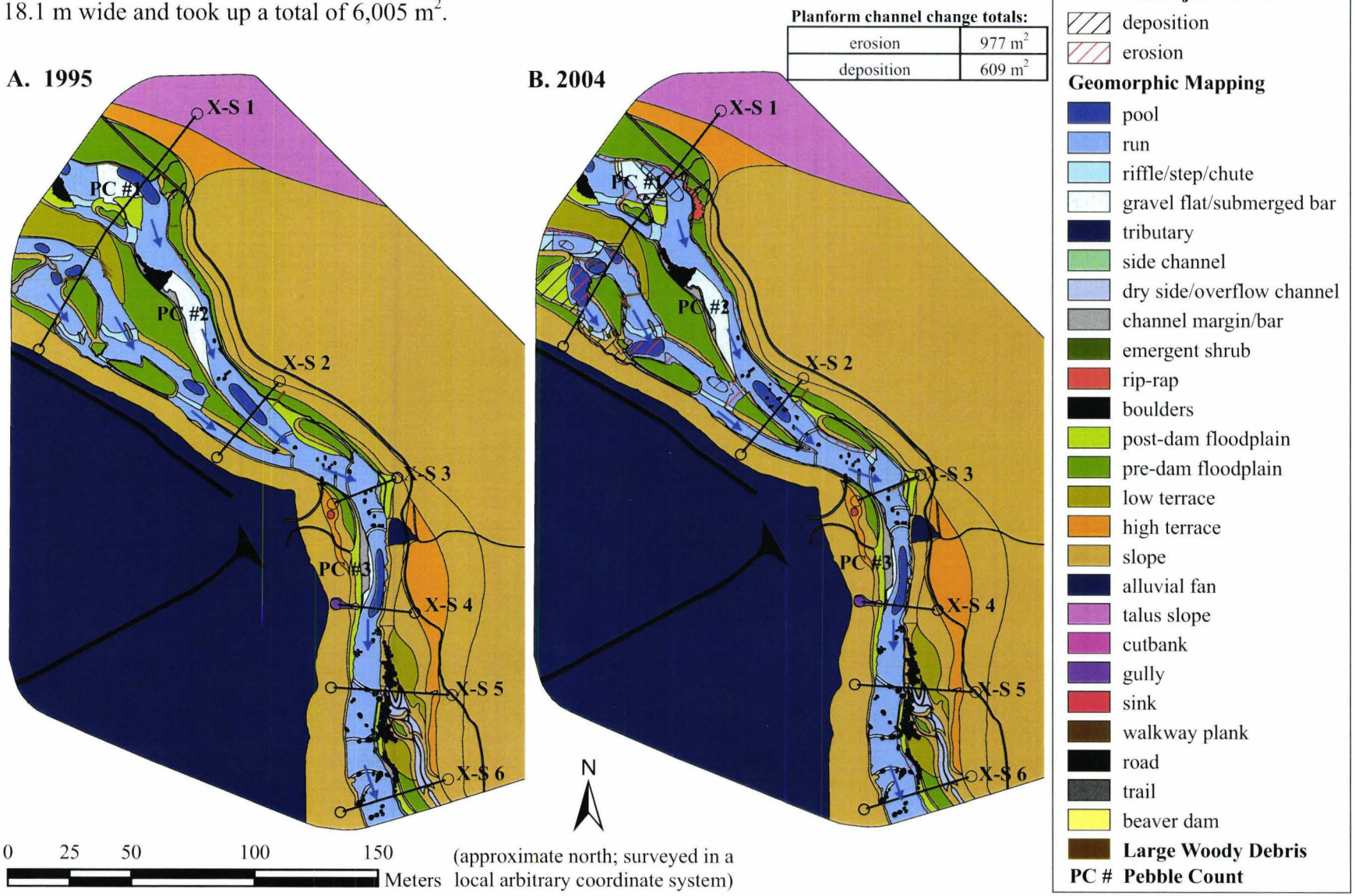
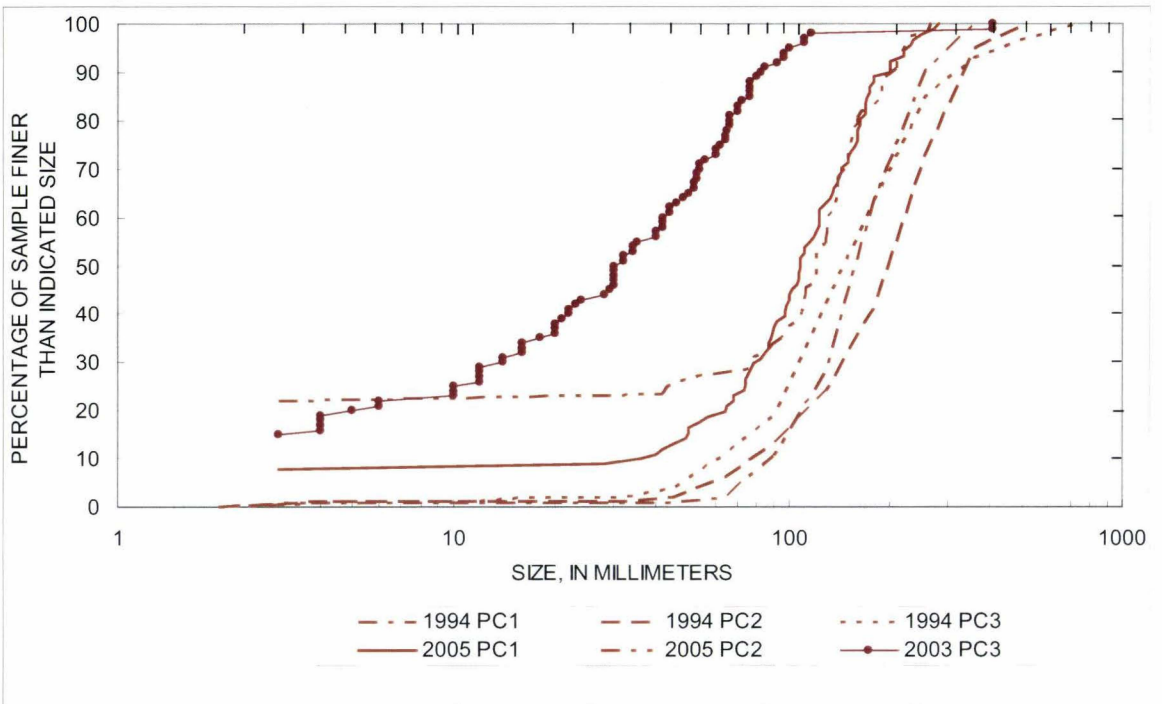



Figure 29. Bed surface substrate measurements for three pebble count sites at Rock Creek monitoring reach. Samples were collected from active depositional zones in 2003, and 2005, at the same locations as those of 1994.